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EVALUATION OF BACKGROUND METALS CONCENTRATIONS IN ARIZONA SOILS

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Prepared for:

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LIST OF ACRONYMS

AAS	Atomic Absorption Spectroscopy
	CVAAS Cold Vapor AAS FAAS Flame AAS GFAAS Graphite Furnace AAS
ADEQ	Arizona Department of Environmental Quality
ADHS	Arizona Department of Health Services
AES	Atomic Emission Spectroscopy
	DCAAES Direct Current Arc Atomic Emission Spectroscopy ICP-AES Inductively Coupled Plasma AES ICP-MS ICP-Mass Spectroscopy FAES Flame AES
EP Tox	Extraction Procedure Toxicity Test
EPA	U.S. Environmental Protection Agency
EREA	Office of Emergency Response and Environmental Analysis of ADEQ, currently known as the Office of Waste Programs
GWPGL	Groundwater Protection Guidance Level
HBGL	Health-Based Guidance Level
INAA	Instrumental Neutron Activation Analysis
MCL	Maximum Contaminant Level
ORAI	Office of Risk Assessment and Investigations of ADHS
OWP	Office of Waste Programs
RCRA	Resource Conservation and Recovery Act
TCLP	Toxicity Characteristic Leaching Procedure
USGS	U.S. Geological Survey
WQARF	Water Quality Assurance Revolving Fund (Arizona)
XRFS	X-Ray Fluorescense Spectroscopy

1.0 INTRODUCTION

1.1 PROJECT SCOPE AND OBJECTIVE

The Arizona Department of Environmental Quality (ADEQ) retained The Earth Technology Corporation (Earth Technology) to a task assignment to develop a database on background metals concentrations in Arizona. "Background metals concentrations" refers to the concentrations of metals that occur naturally in the insite soil and is separate from man-made contamination. This database would then be used as a guideline for evaluating soil cleanup standards at sites where remediation of metals-contaminated soil would be required. ADEQ selected 19 metals to be addressed during this investigation: aluminum, antimony, arsenic, barium, beryllium, cadmium, chromium, cobalt, copper, lead, mercury, molybdenum, nickel, selenium, silver, thallium, uranium, vanadium, and zinc.

To meet the objective of the task assignment, Earth Technology divided the project into four tasks:

- Task 1 - Initial Data Review and Definition of Sub-areas
- Task 2 - Literature Review and Records Search
- Task 3 - Data Evaluation and Database Generation
- Task 4 - Review of Analytical Techniques and Methods.

A description of the activities performed during each task is provided below.

<u>Task 1 - Initial Data Review and Definition of Sub-areas</u>

During this task, Earth Technology compiled and reviewed geographic, geomorphic, soils, hydrologic, and mineralogic data for Arizona. Because large volumes of data were anticipated for this investigation, Earth Technology proposed to limit the study area to the Phoenix and Tucson urban areas. By concentrating on these areas, a comprehensive database could be developed that would more accurately reflect the range and variation of concentrations of background metals in areas where remedial activities are commonly performed. In addition, Earth Technology planned to define sub-areas within the Phoenix and Tucson areas. These sub-areas were to identify differing metal constituents and/or concentrations resulting from naturally occurring features or phenomena. The subareas identified during

Task 1 were to be further defined or modified based on the data (or lack of data) compiled during subsequent tasks. However, after conducting initial literature reviews, available information on the Phoenix and Tucson areas was found to be insufficient to use as a database, and the study area was enlarged to encompass Arizona as a whole.

<u>Task 2 - Literature Review and Records Search</u>

Earth Technology compiled and reviewed published literature and unpublished data, from the public and private sectors, on the background concentrations of metals in soils. The sources of information consulted during the records searches are identified and discussed in Section 2.0.

<u>Task 3 - Data Evaluation and Database Generation</u>

During Task 3, the compiled data were evaluated based on several criteria including two sample data sets, sample location, concentration, and analytical technique used for analysis of metals. Depth-specific analytical data were available in some locations; however, these data were not extensive enough to characterize vertical zones in the subsurface. Where appropriate, this depth-specific analytical information is reflected in the database.

<u>Task 4 - Review of Analytical Techniques and Methods</u>

The common analytical techniques used to assess the concentration of metals in soil were compiled and reviewed. This evaluation of analytical techniques was conducted concurrently with Task 3 to assist with the screening of data prior to its inclusion in the database. Based on this evaluation, appropriate and reliable analytical techniques for use during remedial investigations have been identified and are discussed in this document.

1.2 BACKGROUND

In 1986, the Office of Emergency Response and Environmental Analysis, currently known as the Office of Waste Programs (OWP), of ADEQ requested a set of "soil cleanup levels for metal contaminants." These data were developed by the Office of Risk Assessment and Investigations (ORAI) of the Arizona

Department of Health Services (ADHS, 1986). The risk assessment approach used to develop soil cleanup levels assumed a daily ingestion of 10 grams of soil during play or gardening. The risk assessment metal concentration was not to exceed a daily dose equivalent to the ingestion of 2-liters of water containing the drinking water maximum contaminant level for each metal (ADHS, 1986).

Using this risk assessment method, ADHS calculated a soil concentration for the 19 metals equivalent to the existing maximum contaminant level (MCL) for drinking water. To establish soil cleanup levels, the equivalent soil concentration was compared to the range of metal concentrations in natural soils as determined by Conner and Shacklette (1975) for the contiguous United States. Because it would be unreasonable to expect the cleanup level to be lower than naturally occurring metals concentrations, the ADEQ's suggested cleanup levels for most of the metals were based on the maximum concentration detected in natural soils (ADHS, 1986). The suggested 1986 soil cleanup levels derived by this process, and the associated range of concentrations reported for soils in the contiguous United States (Conner and Shacklette, 1975) are presented in Table 1-1.

ADHS (1986) emphasized that concentrations developed by the ORAI were suggested cleanup levels and consequently could not be legally enforced. ADHS suggested that situations would arise in which a health risk assessment would justify a higher concentration or require a lower concentration. In general, the suggested soil cleanup levels developed in 1986 did represent the results of a consistent analytical approach based on single risk assessment. The management approach of the cleanup levels, however, was inconsistent (i.e., levels were adjusted for laboratory detection limits and background concentrations).

In 1989, ADEQ and ORAI re-evaluated the 1986 "Suggested Cleanup Levels" for soils in order to develop a new set of guidelines. Two areas of concern were considered in developing these guidelines: (1) if contaminated soil were to be ingested, and (2) if groundwater were threatened due to contaminated soil. They concluded that two types of soil guidance levels were needed: ingestion health-based guidance levels (HBGLs) and groundwater protection guidance levels (GWPGLs). As a result, draft HBGLs (for 230 chemicals including 19 metals) were developed by ORAI and provided to ADEQ in early 1990 (Table 1-1). The HBGLs were developed using a consistent health-risk analysis methodology. These values do not take into account risk management factors such as background levels or laboratory detection limits (as was the case for the 1986 "suggested soil clean-up levels") (ADHS, 1990).

TABLE 1-1. ADHS DRAFT HEALTH-BASED CLEANUP/ GUIDANCE LEVELS FORMETALS IN SOIL

METAL	RANGE OF LEVELS IN NATURAL SOILS(a) (mg/kg)	1986 SUGGESTED SOIL CLAENUP LEVEL(b) (mg/kg)	DRAFT 1990 INGESTION HBGL(d) (mg/kg)	"WORST POSSIBLE CASE INGESTION HBGL(d) (PICA CONDTION) (mg/kg)
ALUMINUM	Not available	15	1,500	15
ANTIMONY	<150 - 500	500	60	0.6
ARSENIC	<0.2 - 97	100	1,000	10
BARIUM	70 - 5,000	5,000	100,000	1,000
BERYLLIUM	1 - 7	10	0.14	0.0014
CADMIUM	1 - 10	10	100	1
CHROMIUM	3 - 1,500	1,500	2,000	20
COBALT	3 - 50	50	14	0.14
COPPER	2 - 300	300	26,000	260
LEAD	<7 - 700	700	400	4
MERCURY	<0.01 - 4.6	5	40	0.4
MOLYBDENUM	<3 - 7	15	1,400	14
NICKEL	<3 - 700	700	2,000	20
SELENIUM	<0.1 - 4.3	10	900	9
SILVER	<0.5 - 5	10	1,000	10
THALLIUM	Not available	5	10	0.1
URANIUM	Not available	None listed	700	7
VANADIUM	7 - 500	500	140	1.4
ZINC	10 - 2,000	2,000	100,000	1,000

Note:
(a) Source: Conner and Shacklette, 1975. This publication was also used by California regulators to develop cleanup standards
(b) Source: ADHS, 1986
(c) HBGL = Health-based guidance level, Source: ADHS, 1990
(d) Soil ingestion health based guidance level for the "worst possible case" involving an individual prone to eating soil, such as a child with Pica.

The HBGLs represent human ingestion levels that are unlikely to result in deleterious effects during long-term exposure; they are estimated to be preventative of a toxic dose by a systemic toxicant and protective to 1 in 1 million cancer risk level for carcinogenic compounds. The HBGL values for chemical contaminants in soil are expressed in milligrams per kilogram (mg/kg) and were based on an average daily ingestion of soil during a lifetime of 70 years. The average soil ingestion values suggested by the U. S. Environmental Protection Agency (EPA) are 0.2 grams per day for children 1 to 6 years of age and 0.1 grams/day for ages 7 to 70. "Worst possible case" HBGLs (involving an individual prone to eating soil, such as a child with Pica) are 1/100 of the soil ingestion HBGL (Table 1-1). This guidance level may be most useful in areas of possible high physical exposure such as a residential area or areas used for recreational activities like parks, lakes, and playgrounds.

After the HBGL document is released in a final form, a follow-up document will be issued describing how the HBGLs will be utilized as guidance in ADEQ regulatory programs. The GWPGLs are currently being developed by ADEQ. GWPGLs will represent guidance levels in soil that are estimated to be protective of groundwater quality in the underlying aquifer.

Sources for most of the information for risk analysis were EPA data appearing in the Federal Register; EPA Health Advisories, EPA Superfund Public Health Evaluation Manual, EPA Integrated Risk Information System (IRIS), and the National Academy of Science Drinking Water and Health Series (ADHS, 1990).

2.0 REVIEW OF DATA, LITERATURE, AND ANALYTICAL TECHNIQUES

Organizations from both the public and private sectors were contacted during the initial data review and literature search. EPA publications and analytical laboratory techniques were also reviewed to compile data on analytical techniques used for detecting metals in soil. A list of the organizations contacted during this project and a summary of the literature reviewed are presented in Sections 2.1 and 2.2, respectively. Analytical techniques for analysis of metals in soil are discussed in Section 2.3.

2.1 DATA ACQUISITION

A total of 62 people were contacted in 16 public and private organizations to locate data on background concentrations of metals in Arizona soil. Although volumes of data on metals can be obtained for mining areas across Arizona, mining companies were not contacted as part of this project because: (1) the rural location of most mining operations would not be relevant to the Phoenix and Tucson metropolitan areas, and (2) the inherent bias of analytical data generated at mine sites.

The organizations contacted (except for ADEQ) and a brief description of the information obtained are listed in Table 2-1. In addition to these contacts, 9 sets of background soil data (62 samples), which included total metals analyses, were acquired from ADEQ files at the following units:

- Resource Conservation and Recovery Act (RCRA) Compliance Unit
- Remedial Projects Unit/Water Quality Assurance Revolving Fund (WQARF)
- Groundwater Hydrology Section
- Site Discovery and Hazard Evaluation Unit.

Additional background soil data were available in ADEQ records; however, the majority of these data did not include analysis for total metals concentrations.

TABLE 2-1. ORGANIZATIONS CONTACTED (Excluding ADEQ)

ORGANIZATION	LOCATION	INFORMATION OBTAINED*
Arizona Commission of Agriculture and Horticulture/ State Agricultural Laboratory	Phoenix, AZ	No data available.
Arizona Department of Geology and Mineral Technology	Tempe, AZ	No data available.
Arizona Department of Health Services	Phoenix, AZ	Connor and Shacklette, 1975
Arizona Department of Mines and Mineral Resources	Phoenix, AZ	Keith et al., 1983
Arizona Geological Survey	Tucson, AZ	Pierce, 1984, 1985 Demsey, 1988, 1989 Pearthree, et al., 1988
Arizona State Mine Inspector	Phoenix, AZ	No data available.
Arizona State University	Tempe, AZ	Pewe et al., 1976
U.S. Bureau of Land Management/ Hydrology Unit	Phoenix, AZ	No data available.
U.S. Department of Agriculture/Soil Conservation Service	Phoenix, AZ	No data available.
U.S. Forest Service/ Agriculture Department	Tucson, AZ	No data available.
U.S. Geological Survey/Geology Division	Flagstaff, AZ	No data available.
U.S. Geological Survey/ Water Resources Division	Tempe and Tucson, AZ	USGS, 1974
U.S. Soil Conservation Commission Office	Phoenix, AZ	No data available.
Northern Arizona University	Flagstaff, AZ	No data available.
University of Arizona, Soil and Water Science Department	Tucson, AZ	Soils data not made available for this report. Unknown if data contain metals concentrations for background samples.

Note: * See Section 5.0 for full citation and Section 2.2 for discussion of material.

2.2 LITERATURE REVIEW

Twenty-one documents were identified through the organizations contacted (Table 2-1), that contained data of significance to this project. Of these 21 documents, 7 were professional papers, 11 were published maps, and 3 were published books. Approximately 10 other published books were reviewed but were found not to contain clearly applicable data. A brief review of the publications used in this study follows:

Arizona Department of Health Services

Publication: "Background Geochemistry of Some Rocks, Soils, Plants, and Vegetables in the Conterminous United States" (Connor and Shacklette, 1975).

Background metals concentrations in soil for the contiguous United States. However, this publication did not contain any soils data for Arizona.

Arizona Department of Mines and Mineral Resources

Publication: "Metallic Mineral Districts and Production in Arizona" (Keith et al., 1983).

Contains a map and descriptions of the mineral districts in Arizona. Tonnage data and concentrations (in percent) of the 19 metals were compiled for each mineral district within the surface-water drainage basins of Phoenix and Tucson. These data are discussed in Section 3.0.

Arizona Geological Survey

Publication: "The Mogollon Escarpment" and "Arizona's Backbone: The Transition Zone" (Pierce, 1984, 1985).

Describes the three geomorphic (physiographic) provinces in Arizona. Both Phoenix and Tucson are within the Basin and Range Physiographic Province which includes the southern and western portions of the state.

Publications:

"Geologic Map of Pima and Santa Cruz Counties" (Wilson et al., 1960);

"Geologic Map of Maricopa County" (Wilson et al., 1957);

"Geologic Map of Quaternary and Upper Tertiary Alluvium in the Phoenix North 30' x 60' Quadrangle, Arizona" (Dempsey, 1988);

"Geologic Map of Quaternary and Upper Tertiary Deposits, Tucson, 1' x 2' Quadrangle", (Pearthree, 1988);

"Geologic Map of Quaternary and Upper Tertiary Alluvium in the Phoenix South 30' x 60' Quadrangle" (Depsey, 1989);

Publication: "Environmental Geology of the Tempe Quadrangle, Maricopa County" (Pewe et al, 1976). Geologic and geomorphic data used to define the limits of geomorphic provinces within the Phoenix and Tucson areas.

Publication: "A Geochemical Study of Alluvium Copper Deposits in Pima County, Arizona" (Huff et al., 1970).

Provides analytical results of several hundred stream sediment and soil samples over a known copper deposit.

Arizona State University Library

Publication: "Chemical Analysis of Soils and Other Surficial Materials of the Contiguous United States" (Boerngen and Shacklette, 1981).

Contains site-specific data summarized in U. S. Geological Survey (USGS) Professional Paper 1270 (Boerngen and Shacklette, 1984). The locations of the 47 samples in Arizona as well as the actual analytical data for each location are presented. The data from this publication are summarized in Section 3.1.1 and plotted on Plate 1.

Publication: "Element Concentrations in Soils and Other Surficial Materials of the Contiguous United States" (Boerngen and Shacklette, 1984).

Contains a larger sampling database than Connor and Shacklette (1975), including general analytical data for the western and eastern United States (including 47 soil samples collected in Arizona). The soil samples were analyzed for the metals specified in the task assignment except cadmium, silver, and thallium. Measured element concentrations for each specific data point were not presented in this report but are presented in USGS Open-file Report 81-197 (Boerngen and Shacklette, 1981).

Publication: "Heavy Metals in Soils" (Alloway, 1990).

Describes the analytical techniques used to identify the concentration of metals in soil, as well as key soil properties affecting the accumulation of metals in soils. This publication also contains a detailed description of the origin of each metal in soil and its chemical behavior. The discussion of analytical techniques (presented in Section 2.3) was derived from the information presented in this publication.

Publication: "Landscapes of Arizona - The Geological Story" (Smiley et al., 1984).

Describes the physiographic provinces and geomorphology of Arizona.

Publication: "The Geomorphic and Paleoclimatic Significance of Alluvial Deposits in Southern Arizona" (Melton, 1965).

Describes alluvial fan deposits within the surface-water drainage basin surrounding Tucson, Arizona.

U.S. Department of Agriculture - Soil Conservation Service

Publications:

"General Soils Maps of Pima County" (U.S. Dept. of Agriculture, 1974);

"General Soils Map of Maricopa County" (Hartman, 1973);

"Soil Survey of Aguila-Carefree Area, Parts of Maricopa and Pinal Counties"; (Camp, 1986);

"Soil Survey Eastern Maricopa and Northern Pinal Counties Area" (Adams, 1974);

Maps of soils for the Phoenix and Tucson areas.

U.S. Geological Survey, Water Resources Division

Publication: "Hydrologic Unit Map - 1974, State of Arizona" (USGS, 1974).

Identifies the surface-water drainage basins in Arizona.

U.S. Environmental Protection Agency

Publication: "Test Methods for Evaluating Solid Waste" (EPA, 1986).

Provides detailed descriptions of the analytical methods recommended by EPA to assess the concentration of metals in solid waste.

2.3 SOLUTION-SAMPLE ANALYTICAL TECHNIQUES FOR ANALYSIS OF METALS IN SOILS

Atomic spectroscopic methods are the most commonly employed methods in the waste management field. These techniques use an acid dissolution of soil for total metals analysis. Two types of dissolution procedures can be performed: (1) total analysis involving dissolution of the soil sample with hydrofluoric acid (an extremely aggressive acid); or (2) pseudo-total analysis using mineral acids such as hydrochloric (HCl), nitric (HNO_3), or sulfuric acid (H_2SO_4).

Decomposition of soil samples is conducted in vessels made of polypropylene or polyethylene because hydrofluoric acid cannot be stored or used in glass vessels. The need to use pure hydrofluoric acid can be avoided by using acid vapor in an apparatus designed for this purpose. Analytical laboratories typically do not use this dissolution procedure due to the strength of the acid and procedure requirements.

The procedure most commonly used in the waste management field is pseudo-total analysis (strong acid digestion). Several mineral acids and their mixtures are used for the dissolution and extraction of elements from soils. Although the acids do not dissolve silicates or silica completely, they are vigorous enough to dissolve the heavy metals not bound to silicate phases. Most heavy metal pollutants fall into this category.

There are several atomic spectroscopic methods that involve analysis of acid-solution samples. Two main techniques, Atomic Absorption Spectroscopy (AAS) and Atomic Emission Spectroscopy (AES), are widely used for the determination of most metals. For both AAS and AES, these methods and the metals for which these analyses can be performed are briefly described below and are compared in Table 2-2. Uranium cannot be analyzed for by these techniques as it emits gama-radiation induced by neutron irradiation and is commonly detected by use of a geiger counter.

<u>Atomic Absorption Spectroscopy (AAS)</u>

Atomic absorption spectroscopy is based on the free atom of an element absorbing light at wave-lengths characteristic of that element and determined by its outer electronic structure. The extent of that absorption is a measure of the number of atoms in the light path. This technique provides a moderate to high degree of element specificity and is the method most widely used for assaying of ores. There are three types of AAS: Flame (FAAS), Graphite Furnace (GFAAS), and Cold Vapor (CVAAS). Conventional FAAS detection limits are in the range 1 to 200 mg/kg for total metals in soils. The technique is rapid, and sample handling, measurement, computation and printout are available in automated form.

The limitations of FAAS in sensitivity and the large dilution introduced by the expanding flame gases of the premised air/acetylene flame have been overcome by the use of graphite furnace atomic absorption (GFASS). This technique generally takes the form of a cylinder of graphite heated by the passage of an electric current through it. Because the whole sample is atomized, and because the atomic vapor produced is partly confined within the graphite tube, the sensitivity of GFAAS is 10- to 100-fold greater than that of FAAS (Alloway, 1990).

Cold vapor atomic absorption spectroscopy (CVAAS) is typically performed on a flame or graphite furnace AAS system but uses a mercury analyzer attachment in place of the flame or furnace attachments. This technique is used solely for analysis of mercury in unpolluted or polluted soils (normal graphite furnace methods are not sensitive enough for determinations of mercury in soil.) An oxidative acid digestion procedure is required to destroy organic matter and is followed by reduction of mercury compounds to elemental mercury for analysis in the vapor phase. Because mercury vapor is monatomic, an atomic absorption measurement can be made in the cold mercury vapor released from the reduced solution. The detection limit for CVAAS analysis of mercury is listed in Table 2-2 under both flame and furnace techniques because the same AAS system is used.

Table 2-2 indicates the metals for which FAAS and GFAAS analyses can be performed in accordance with the EPA (1986) SW-846 laboratory manual for analysis of solid wastes. The detection limits listed are examples of what may be attainable for each metal using these methods.

Atomic Emission Spectroscopy (AES)

With this technique, a sample solution is nebulized by an energy source such as a flame, an inductively coupled plasma, or a graphite furnace. The source acts not only to atomize the sample but also to excite the atoms to emit their characteristic spectral lines. The intensities of the emitted lines are a function of the concentration of the atoms in the exciting source and hence of the solution content. Atomic Emission Spectroscopy differs from AAS in that AES can readily provide simultaneous, very rapid, sequential, multi-element analysis of a single sample solution.

Two types of AES methods, Flame Atomic Emission Spectroscopy (FAES) and Inductively Coupled Plasma-Atomic Emission Spectroscopy (ICP-AES), are discussed below. ICP-Mass Spectroscopy (ICP-MS) is a highly precise but expensive analytical technique that is still in research stages and is not accepted as a viable analytical technique by the EPA. Therefore, this technique is not addressed in this report.

Historically, flame emission spectroscopy (FES) preceded FAES. In the 1950's and 1960's, under the name of flame photometry, FES was used to determine alkali and alkaline earth metals and a few minor elements. The use of FES has largely been replaced by AAS techniques because of better element specificity and freedom from spectral interference effects using AAS. Therefore, this method is not presented in Table 2-2.

Inductively Coupled Plasma-Atomic Emission Spectroscopy (ICP-AES) uses the emission from the flame-like plasma formed on a quartz torch by coupling a radio frequency electromagnetic field to the electrons in an ionized argon plasma. Plasma is heated by use of electrical current through the plasma. As a result of the heating and torch parameters, the plasma is shaped into a thyroidal or "donut" form. Sample aerosol is directed into the central hole of the plasma donut. Temperatures in the plasma are typically 6,500°K in the analytical measuring zone. At these high temperatures, atomization is virtually complete for most elements, and strong atomic and ionic line emissions can occur. Typical detection limits are shown on Table 2-2.

Analysis by ICP-AES is the preferred technique for most metals due to rapid multi-element analysis. However, AAS techniques are usually preferred over ICP-AES for analysis of arsenic, copper, lead, mercury, selenium, and thallium due to the lower detection limits of AAS. Detection limits for ICP-AES are generally higher than GFAAS but lower than FAAS. This is due to the fact that ICP-AES is susceptible to spectral interference caused from multi-element analysis, which results in higher detection limits than GFAAS. Higher precision of the ICP-AES gives higher detection limits than FAAS. AAS techniques involve single element analysis with longer sample preparation, handling and analysis time than with ICP-AES techniques. Thus, there is a trade-off between speed and detection limits. Unless specifically requested, most laboratories will run metals analysis by ICP-AES for most metals.

3.0 EVALUATION AND CONCLUSIONS

3.1 BACKGROUND CONCENTRATIONS OF METALS IN ARIZONA SOILS

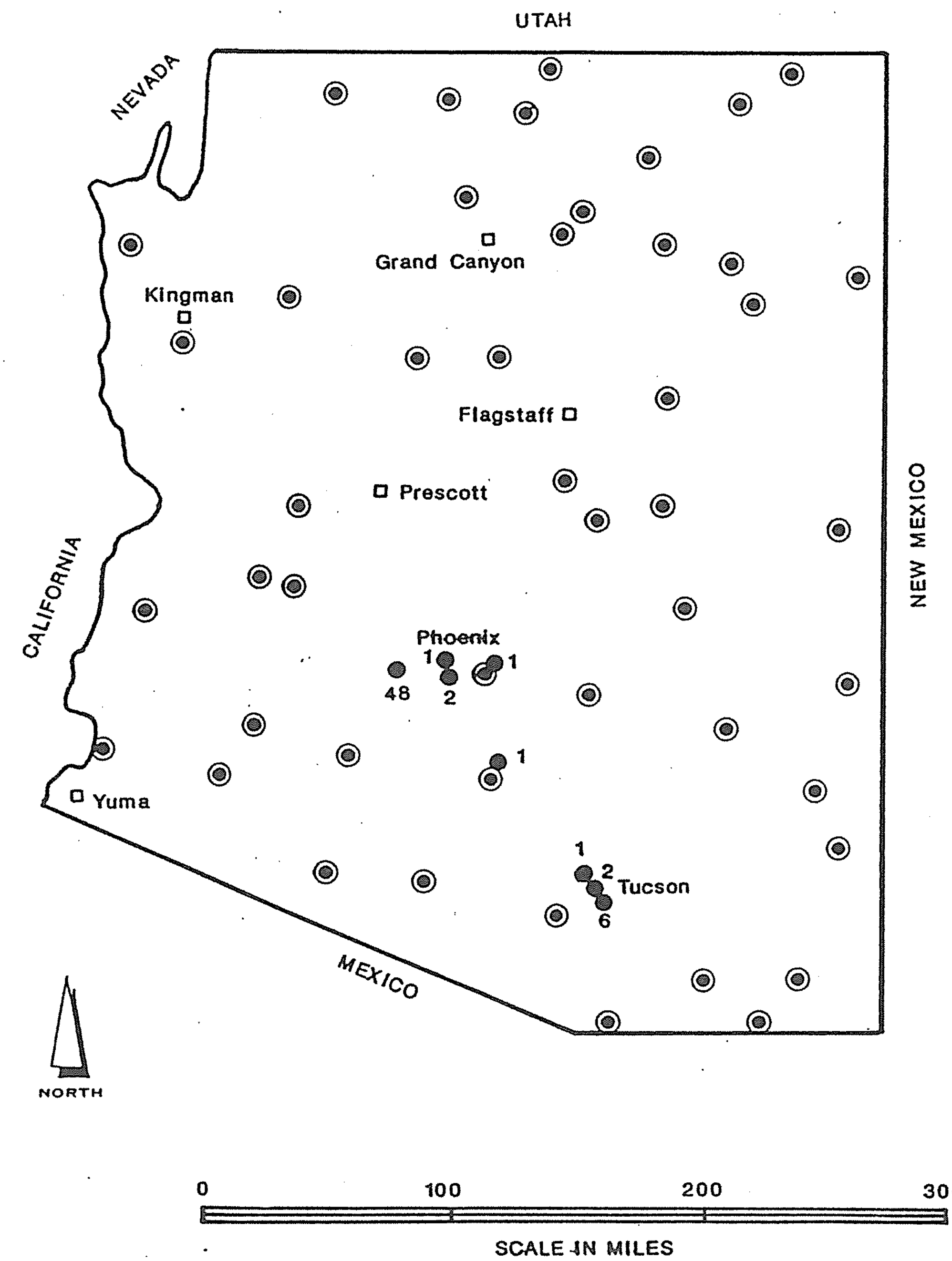
A set of statewide data containing background concentrations of metals in Arizona soil was found during the initial literature review. Other site-specific soil data were obtained during a search of available records maintained by the ADEQ. These site-specific and statewide data, however, were not extensive enough to develop a comprehensive database. Therefore, the database discussed here does not reflect the range and variation of background concentrations of metals in the Phoenix and Tucson urban areas. The database does, however, provide a broad scope of background concentrations of metals in soils that may be used as a guide for site-specific studies.

In this section, the data obtained during the initial data review and records search was evaluated. This evaluation is based on the concentration of selected metals in relation to ADHS guidance levels for metals in soil, and the sample location in relation to physiographic area. Two main sources that provided background concentrations of selected metals in Arizona soil were identified during this project: (1) a set of 47 soil samples collected and analyzed by the U.S. Geological Survey (USGS); and (2) 62 soil samples collected during various site investigations and obtained from records maintained by ADEQ.

3.1.1 USGS Data

The approximate locations of the 47 USGS soil sampling sites are shown in Figure 3-1 and on Plate 1 and are listed in Appendix A (Borengen and Shacklette, 1981). The samples were collected by USGS personnel at approximate 50-mile intervals along routes of travel from one field area to another. Borengen and Shacklette noted that, if possible, the sampling sites were selected to represent surficial materials that were minimally altered from their natural condition. The authors noted that, in practice, this site selection procedure necessitated the collection of samples away from roadcuts and fills. The materials sampled included soil, beach and dune sands, and stone lithosols. Most samples were collected at a depth of about 8 inches to avoid the effects of surface contamination.

The 47 soil samples collected by the USGS were obtained and analysed sometime during a 14-year period from 1961 to 1975. The methods of analysis used by the USGS to determine the concentration of selected metals in the soil samples were as follows:



EXPLANATION:

◎ Approximate Locations of USGS Soil samples (One sample collected per site)

● 48 Approximate Locations of ADEQ Soil Samples, Showing Number of Samples Taken at Each Location

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APPROXIMATE LOCATION OF USGS AND ADEQ SOIL SAMPLES

Figure 3-1

12-91

- o FAAS: mercury and zinc
- o GFAAS: mercury
- o X-Ray Fluorescence Spectroscopy (XRFS): selenium and silver
- o Direct-current Arc Atomic Emission Spectroscopy (DCAAES): aluminum, antimony, arsenic, barium, beryllium, cadmium, chromium, cobalt, copper, lead, molybdenum, nickel, thallium, and vanadium.

Unlike the solution-sample analytical techniques of FAAS and GFAAS, XRFS and DCAAES use a solid-sample and differ in the method used to prepare samples and quantify elements. XRFS and DCAAES are not used in the wastemanagement field because of poor resolution and sensitivity and are only suitable as a qualitative technique rather than a quantitative technique. The methods of analysis used for some elements were changed to FAAS and GFAAS during the course of the USGS study.

The analytical results for these samples are provided in Appendix A. From these data, the average, standard deviation, maximum, and minimum concentrations of metals were calculated and are shown in Table 3-1. The USGS soil samples represent a broad coverage for the state and may be representative of what metals concentrations might be for the state as a whole.

3.1.2 ADEQ Data

The approximate locations of the 62 ADEQ soil samples are shown on Figure 3-1 and are identified on Plate 1 as 48a through 48f, 49 through 55, 56a through 61h, and 62. These samples were specifically noted as background samples in the investigations and were obtained from 10 sites removed from known site contamination. The depth of sample acquisition ranged from 0.25 feet to 9 feet below ground surface. The location of, and analytical results for, these samples are provided in Appendix B. The average, standard deviation, maximum, and minimum concentrations of metals for the ADEQ samples are also shown on Table 3-1. In general, the metals concentrations for ADEQ samples are below those of the USGS samples. The ADEQ samples are from the greater Phoenix and Tucson areas and may be representative of what metals concentrations might be for these areas. These data sets represent the best available sources of background data without conducting a state-wide soil sampling and analysis program.

TABLE 3-1. CONCENTRATIONS OF SELECTED METALS DETECTED IN USGS AND ADEQ SOIL SAMPLES FROM ARIZONA3.33

METAL	ADEQ GUIDANCE LEVELS(a) DRAFT 1990 INGESTION HBGL(mg/kg)	"WORST POSSIBLE CASE INGESTION HBGL(b)(mg/kg)	USGS SOIL SAMPLES(c) CONCENTRATIONS OF METALS AVERAGE (mg/kg)	STANDARD DEVIATION (mg/kg)	MAXIMUM (mg/kg)	MINIMUM (mg/kg)	ADEQ SOIL SAMPLES CONCENTRATIONS OF METAL AVERAGE (mg/kg)	STANDARD DEVIATION (mg/kg)	MAXIMUM (mg/kg)	MINIMUM (mg/kg)
ALUMINUM	1,500	15	55,213	28,246	100,000	30,000	10.654	2,859	16,817	6,200
ANTIMONY	60	0.6	<1	0	<1	<1	1.7	1.81	3.8	<0.4
ARSENIC	1,000	10	9.8	17.2	97	1.4	9.4	3.8	24	3.1
BARIUM	100,000	1,000	565	269.7	1,500	200	161.3	30.5	230	72.6
BERYLLIUM	0.14	0.0014	0.52	1.01	5	ND	1.1	0.9	2.0	0.3
CADMIUM	100	1	–	–	–	–	0.4	0.4	1.7	ND
CHROMIUM	2,000	20	61.3	66	300	5	17.5	7.0	34	5.4
COBALT	14	0.14	9.7	6.3	30	ND	–	–	–	–
COPPER	26,000	260	30	30.5	200	5	16.6	5.9	27	6.0
LEAD	400	4	23.4	20.7	100	ND	7.7	4.8	24.5	ND
MERCURY	40	0.4	0.10	0.13	0.57	0.01	0.05	0.2	0.25	ND
MOLYBDENUM	1,400	14	3.0	2.8	3.0	ND	–	–	–	–
NICKEL	2,000	20	27.5	30.5	150	ND	18.2	5.3	28	9.2
SELENIUM	900	9	0.30	0.26	1.6	<0.1	0.6	0.3	1.0	<0.4
SILVER	1,000	10	–	–	–	–	0.5	0.4	0.8	<0.05
THALLIUM	10	0.1	–	–	–	–	0.7	0.4	<1.0	0.5
URANIUM	700	7	2.1	1.0	3.4	1.1	–	–	–	–
VANADIUM	140	1.4	71.3	46.4	300	10	12	16.7	23.8	<0.2
ZINC	100,000	1,000	62.1	34	150	12	38.9	16.4	81	15

Notes:

(a) ADHS, 1990
(b) HBGL = Health-based guidance level (ADHS, 1990)
(c) Borengen and Shacklette, 1991
ND = None detected
– = No data available.

3.1.3 ADEQ Guidance Levels

The USGS and ADEQ analytical data were compared with the ADEQ soil ingestion HBGLs to evaluate the differences between the two sets of analytical data and the HBGLs. For instance, the average and maximum concentrations of aluminum and beryllium in these two data sets (USGS and ADEQ) exceed the ADEQ ingestion HBGLs. The USGS maximum for cobalt and vanadium also exceeds the ingestion HBGLs. The following sections evaluate the USGS and ADEQ analytical results with respect to the draft soil ingestion HBGLs.

Soil Ingestion-Health Based Guidance Levels

As shown on Table 3-1, the draft ADEQ soil ingestion HBGL for aluminum (1,500 mg/kg) is 36 times less than the USGS average of 55,213 mg/kg and is 7 times less the average value for ADEQ samples. Based on these data, soil background levels for aluminum may exceed the draft HBGL throughout most, if not all of the state. The USGS average concentrations for beryllium and USGS maximum concentrations for cobalt and vanadium also exceed the ADEQ ingestion HBGLs. The ADEQ will need to be especially cognizant of these situations during their development of guidelines and will need to evaluate how the HBGLs will be used in ADEQ programs.

Concentrations for the remaining metals (Table 3-1) are below the ingestion HBGLs proposed by ADEQ. If the background metals concentrations are compared with HBGLs that are appropriate for the Pica condition ("worst possible case"), many other metals are found to exceed the HBGL. HBGLs represent concentrations of total metals in soil that are protective of human health. Therefore, in order to evaluate how metals concentrations in a soil compare to the HBGLs, a total metals analysis must be conducted. This should be done on both background samples as well as cleanup verification samples. The most appropriate total metals test that should be used for this comparison is discussed in Section 4.2.

Development of Groundwater Protection Guidance Levels

In addition to the HBGLs, ADEQ intends to develop a separate set of values for soil to protect groundwater quality in the underlying aquifer (ADHS, 1990). These Groundwater Protection Guidance Levels (GWPGLs) will take into account the leachability of metals from soil to groundwater. Therefore, a leachability test must be adopted to standardize comparisons with the GWPGLs. Several standard leach tests have been developed, such as the Toxicity Characteristic Leaching Procedure (TCLP), California Waste Extraction Procedure, Equilibrium Leach Test, and Synthetic Precipitation Leach Test for soils. The Extraction Procedure Toxicity Test (EP Tox) is being replaced by the TCLP and should not be considered as the standard. The results of the leachability test must always be compared to the GWPGLs to ensure that the test is appropriate for the specific geologic and hydrologic site conditions. In order to properly develop the site-specific data for comparison to the GWPGLs, background samples as well as clean-up-verification samples should be analyzed.

3.2 CORRELATING BACKGROUND METALS CONCENTRATIONS WITH PHYSIOGRAPHIC, GEOLOGIC, AND HYDROLOGIC FEATURES

One objective of this study was to evaluate whether background metals concentrations in soils correlate with physiographic province, geomorphology, surface water basins, and/or geochemistry. The hypothesis is that if once a landform, such as an alluvial fan, is delineated and the origin of the parent material identified, then the geochemistry of the soil should resemble that of the parent material. In undisturbed soils, this correlation could be conceivably performed for any size landform. This correlation will be most accurate when dealing with in-situ soils that have gone through minimal weathering and transport (i.e., soil on a mountain slope). Based on the existing statewide USGS database, an attempt was made to correlate metals concentrations to physiographic province. The results of this correlation are discussed below. Plate 1 shows the relationship of both USGS and ADEQ samples to the three physiographic provinces (Basin and Range, Transition Zone, Colorado Plateau) in Arizona.

The available physiographic and geomorphic landform data were sufficient for Tucson, but data for major sections of east Phoenix were not available. Data sources mainly consisted of maps identifying geologic features related to stream sediments, river terraces, alluvial fans, and exposed bedrock. (These maps are identified in Section 2.2 of this report). Background data (on metals concentrations in these soils) that are needed to define these finite subareas are simply not available. However, some correlations between metals concentrations in USGS soil samples and selected mineral districts can be made on a local basis. This correlation is discussed below.

USGS samples 1 through 4, 8 through 11, 13 through 18, and 32 through 36 are all located within the limits of the Colorado Plateau (Plate 1). Colorado Plateau mineral deposits identified from the Metallic/Mineral Districts Map (Keith et al., 1983) are mostly uranium deposits. Samples 1, 4, 8, 17, and 34, were taken in areas close to known uranium deposits (Plate 1). Of these five samples, only sample 8 was tested for uranium (Appendix A). The uranium concentration for this sample was 3.4 mg/kg, which is 1.3 mg/kg above the USGS average, but is below the draft soil ingestion HBGL of 700 mg/kg or the Pica condition HBGL of 7 mg/kg.

Ten other USGS samples were taken close to known mineral deposits within the Transition Zone and Basin and Range Provinces. Samples 16, 29, 38, and 43 were obtained near copper deposits (Plate 1). Of these, sample 29 was found to contain zinc at 100 mg/kg, which is 37.9 mg/kg above USGS average, although far below the draft soil HBGL of 100,000 mg/kg. Sample 38 contained concentrations of 70 mg/kg for both copper and lead, which is 40 mg/kg and 46.6 mg/kg greater than USGS averages for these metals, respectively. The HBGLs for copper and lead are 26,000 mg/kg and 400 mg/kg, respectively. Sample 7, which was taken near a lead-zinc deposit (Plate 1), contained 70 mg/kg of lead and 90 mg/kg of zinc, which is 46.6 mg/kg above the USGS average for lead and 27.9 mg/kg above the USGS average for zinc. These data indicate that soil samples taken in close proximity to mineral deposits may be influenced by the natural concentrations in the ore body.

A comparison of selected average metals concentrations of USGS soil samples from Arizona by physiographic province (Table 3-2) indicates that the metals concentrations are approximately twice as high for the Transition Zone and the Basin and Range provinces than those for the Colorado Plateau. The fact that the majority of the known metallic mineral deposits are located in the southwestern two-thirds of the state supports this finding (based on a limited data set of which not every sample was tested for the metals of concern). Another explanation may be that sampling close to a metallic mineral deposit has caused this correlation. While this is the case in a few instances, the large majority of the samples were taken several miles from known metallic mineral deposits. A more intensive study would need to be conducted in order to confirm this observation.

A second factor that may influence the concentration of metals in soils and alluvial deposits (materials deposited by water) throughout the state is the location of mineral deposits within surface-water drainage basins. Plate 1 delineates the surface-water drainage basins that converge in Phoenix and Tucson. These drainage basins have been superimposed over the known metallic mineral districts within the limits of the basins in order to identify sources of metallic minerals that may contribute to the metals concentrations in soils and alluvium of these basins (Plate 1). Surface water flowing across mineral deposits and associated weathered material dissolves, weathers, and transports grains of metals downstream where they are deposited in soils and alluvial sediments along river banks and flood plains.

TABLE 3-2. COMPARISON OF SELECTED AVERAGE METAL CONCENTRATIONS IN SOIL FROM USGS SAMPLES BY PHYSIOGRAPHIC PROVINCES IN ARIZONA

METAL	AVERAGE CONCENTRATIONS(a) (miligram per kilogram (mg/kg))		
	"WORST POSSIBLE CASE" INGESTION HBGL (b) (mg/kg)	COLORADO PLATEAU	TRANSITION ZONE AND BASIN AND RANGE
ALUMINUM	15	39,118	66,667
ANTIMONY	0.6	1	1
ARSENIC	10	4.4	12.7
BARIUM	1,000	441	617
BERYLLIUM	0.0014	ND	2.5
CADMIUM	1	--	--
CHROMIUM	20	36.7	85.2
COBALT	0.14	5.4	12.8
COPPER	260	14.1	34.4
LEAD	4	13.8	30
MERCURY	0.4	0.05	0.12
MOLYBDENUM	14	ND	0.75
NICKEL	20	12.8	40.5
SELENIUM	9	0.2	0.3
SILVER	10	--	--
THALLIUM	0.1	--	--
URANIUM	7	1.9	2.37
VANADIUM	1.4	39.4	93.8
ZINC	1,000	35.6	72.8

Notes: (a) = Average concentrations calculated from values in Table A-2 in Appendix A
(b) = HBGL - Health-based guidance level (ADHS, 1990)
ND = None detected
-- = No data available.

The upper reaches of the Santa Cruz River and its tributaries drain a portion of the southern part of the state within the Basin and Range physiographic province (Plate 1). Metallic mineral deposits in this area are mainly copper, lead, and zinc ores. The Salt and Verde Rivers and their tributaries drain a significant area of the state in the mountainous physiographic province known as the Transition Zone (Plate 1). Metallic mineral deposits in this area include copper, lead, zinc, manganese, mercury, tungsten, uranium, and iron. These metals continue to be deposited in these basins due to erosion and transport.

Appendix C contains tables that identify each mineral district within the Phoenix and Tucson areas by county, latitude, and longitude, and provides a description of the mineral deposit. A list of the percentage of precious metals extracted from mined materials for selected mineral districts is also provided. These tables may be useful for determining qualitatively what metals may exist downstream of mineral districts but should not be used for quantitative analysis.

The closer weathered material is to its parent material, the more alike the geochemistry of each material will be. This situation is evident in mineral districts where the concentrations of metals in weathered bedrock material are higher than, concentrations in near-surface material (Melton, 1955).

3.3 EVALUATION OF ANALYTICAL TECHNIQUES

According to most analytical laboratories, and based on the detection limits of the methods for the metals studied, the most precise and effective techniques for metals analysis in environmental remediation projects are GFAAS and ICP-AES. In general, lower detection limits can be obtained by GFAAS, and ICP-AES is the most cost-effective method for most metals. The desired detection limit is the factor that generally dictates whether GFAAS or ICP-AES is performed. If detection limits are not a concern, most laboratories will perform analysis by ICP-AES.

Both GFAAS and ICP-AES have detection limits well below the ADEQ draft 1990 soil ingestion HBGLs for all metals except beryllium and thallium. The HGBLs for beryllium and thallium are 0.14 mg/kg and 10 mg/kg respectively. The detection limits of the ICP-AES are above or equal to the HGBLs for these metals (0.5 mg/kg for beryllium and 10 mg/kg for thallium). The detection limits of GFAAS is one of two orders of magnitude below the HGBLs for these metals (0.01 mg/kg for beryllium and 0.5 mg/kg for thallium).

4.0 RECOMMENDATIONS

4.1 RECOMMENDATION FOR STANDARD METALS BACKGROUND SAMPLING PROCEDURES

In order to maintain consistency and validity for background sampling procedures, a few standard sampling protocols should be followed for establishing background conditions at a given site. First, background soil samples must be taken at locations known or at least judged to be free of contamination. Second, if metals contamination at depth is of concern, background soil samples should be taken at the same depth of contamination for comparison. Third, artificial fill soil samples need to be evaluated separately from native in-situ soil samples. Metals concentrations in tilled agricultural soils and fills may be dramatically different from those in native in-situ soils. Fourth, the soil profile needs to be carefully identified and correlated to the samples as soil changes may result in differing concentrations. Fifth, using the arithmetic average of analytical data for a given soil horizon would be more accurate than performing a composite analysis for a soil horizon. The required number of background soil samples must be justified prior to initiation of the investigation.

4.2 RECOMMENDATION FOR ANALYSIS OF TOTAL METALS CONCENTRATIONS IN SOIL

GFAAS should be used when analyzing soil for concentrations of beryllium and thallium, as the detection limits for these metals are well below the draft HBGLs for them. Analysis of mercury is best performed by CVAAS on a graphite furnace. Analysis of the 16 remaining metals can be performed by GFAAS or ICP-AES depending on the desired detection limits, costs, and analysis time.

4.3 RECOMMENDATION FOR GUIDANCE LEVELS

Analytical results of total metals in background soil samples can be compared to a state average (USGS sample data) and ingestion HGBLs to establish site-specific guidance levels for soils. Because HGBLs are based only on a health risk, a site-specific guidance level could be developed by modifying the HGBLs when background metals concentrations exceed the HGBLs. The extent to which guidance levels are modified will depend on the magnitude of the differences between HGBLs and the background averages for the metals.

In order to establish a basis for the groundwater protection guidance level (GWPGL), a standard leach test needs to be adopted and performed for background metals and contaminated soil samples at each site. Since the TCLP procedure approximates natural leaching conditions, it is the most suitable leach procedure to adopt. After GWPGLs are developed, they should be compared with the results of a risk analysis performed to establish the GWPGL for each site.

4.4 RECOMMENDATION FOR DATA COLLECTION AND DATABASE GENERATION

The 109 background metals soil samples collected from 57 sites across the state were not subject to the standard soil sampling protocol performed today in the environmental field. Nevertheless, these samples probably represent background conditions at these locations. Once a standard protocol for background sampling is established, data can be collected from each site and entered into a database. The database should include: 1) if total metals analysis was performed for comparison to the ingestion HBGLs or if TCLP metals analysis was performed for comparison to the GWPGLs; 2) only sampling that is conducted according to an established soil sampling protocol; 3) latitude and longitude; 4) depth of sample; 5) USCS soil classification; 6) sample designations; 7) analytical results using recognized standard analytical methods; and 8) reference as to facility and ADEQ file or literature source. The existing database would be continually updated, and statistical analyses could be performed to assess metal concentration variations throughout the state for use in modifying HBGLs or GWPGLs.

4.5 RECOMMENDATION FOR SAMPLING PLAN

A sampling plan for the metropolitan areas of the state should be developed in order to obtain a more statistical representation for these areas. A statistical study needs to be conducted to determine the number of samples necessary to establish a representative base for these areas. As a possibility for accumulating additional data, soil samples could be collected by ADEQ field personnel as they perform other inspections or investigations.

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5.1 LITERATURE REFERENCES

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6.0 LIMITATIONS

The conclusions, recommendations and professional opinions presented in this report were developed by The Earth Technology Corporation in accordance with generally accepted geological, hydro-geological, and laboratory analytical principles and practices. This warranty is in lieu of all other warranties either expressed or implied.

This report has been prepared for use by ADEQ in developing Ingestion HBGLs and GWPGL for metals in soil. It may not contain sufficient information for the purposes of other parties or other uses. The data, interpretations, conclusions, and recommendations contained herein should be considered to relate only to the specific project and location discussed herein. The Earth Technology Corporation is not responsible for any future conclusions or recommendations that may be made by others, unless we have been given an opportunity to review such conclusions or recommendations and concur in writing.

APPENDIX A

USGS SOIL SAMPLE ANALYTICAL RESULTS, LOCATIONS, AND DESCRIPTIONS

APPENDIX A. USGS SOIL SAMPLE ANALYTICAL RESULTS, LOCATIONS, AND DESCRIPTIONS

Appendix A consists of available USGS background data on metal concentrations in soil samples from across Arizona. This database is comprised of two tables that are a compilation of data extracted from USGS Open-File Report 81-197 (Boerngen and Shacklette, 1981). Table A-1 and A-2 contain the following information:

- Table A-1 lists the location and gives a brief description of each sample
- Table A-2 lists the concentrations in milligrams per kilogram (mg/kg) for each metal for each soil sample.

TABLE A-1. LOCATION AND DESCRIPTION OF USGS SAMPLES OF SURFICIAL SOILS FROM ARIZONA
(Page 1 of 3)

SAMPLE NO.	COUNTY	LATITUDE (Degree, Minute)	LONGITUDE (Degree, Minute)	DEPTH (Feet)	SITE AND SOIL DESCRIPTION
1	APACHE	35° 34'	110° 0'	0.75	COUNTY RD. AT SUNRISE SPRINGS; sandy clay alluvium
2	APACHE	35° 34'	109° 15'	0.1-0.5	ROUTE 264, 2 MILES NORTH ON SAWMILL ROAD; soil not described
3	APACHE	34° 18'	109° 22'	0.75	U.S. 666-180, 15 MILES NORTH OF SPRINGERVILLE; soil over mudstone
4	APACHE	36° 55'	109° 45'	0.75	U.S. 164, CHINLE WASH CROSSING 40 MILES NORTHEAST OF KAYENTA; red sand
5	COCHISE	31° 40'	110° 16'	0.75	ROUTE 82, 2 MILES EAST OF JUNCTION WITH ROUTE 90, WEST OF AIRBANK; soil not described
6	COCHISE	31° 25'	109° 51'	0.75	U.S. 80, 3 MILES EAST OF LOWELL; soil not described
7	COCHISE	31° 40'	109° 37'	0.75	U.S. 666, 1 MILE SOUTH OF ELFRIDA; soil not described
8	COCONINO	35° 56'	111° 23'	0.75	U.S. 89, 7 MILES SOUTH OF JUNCTION WITH U.S. 164; dune sand
9	COCONINO	36° 25'	110° 48'	0.75	U.S. 164-160, 3.5 MILES SOUTH OF COW SPRINGS; red sand
10	COCONINO	34° 33'	111° 18'	0.75	ROUTE 87, AT CLINTS WELL; dark forest soil
11	COCONINO	35° 14'	111° 47'	0.75	INTERSTATE 40, 5 MILES EAST OF FLAGSTAFF; B horizon dark forest soil
12	COCONINO	35° 32'	113° 20'	0.75	U.S. 66, 32 MILES NORTHWEST OF SELIGMAN; arid light B horizon
13	COCONINO	36° 6'	111° 15'	0.1-0.5	ROUTE 264, 1 MILE EAST OF MOENKOPI; soil not described
14	COCONINO	36° 55'	112° 30'	0.1-0.5	U.S. 89, AT GLEN CANYON DAM AT PAGE; sand
15	COCONINO	36° 10'	112° 4'	0.1-0.5	AT NORTH RIM BY GRAND CANYON LODGE; loamy soil
16	COCONINO	36° 43'	112° 14'	0.75	U.S. 89A, 1 MILE SOUTH OF JACOB LAKE LODGE; black rocky loam
17	COCONINO	36° 40'	111° 40'	0.1-0.5	U.S. 89, JUNCTION WITH U.S. 89A AT BITTER SPRINGS; sandy
18	COCONINO	35° 13'	112° 23'	0.75	U.S. 66-89, 5 MILES EAST OF ASH FORK; lithosol from volcanic extrusive lava

Source: Boerngen and Shacklette, 1981.

TABLE A-1. LOCATION AND DESCRIPTION OF USGS SAMPLES OF SURFICIAL SOILS FROM ARIZONA
(Page 2 of 3)

SAMPLE NO.	COUNTY	LATITUDE (Degree, Minute)	LONGITUDE (Degree, Minute)	DEPTH (Feet)	SITE AND SOIL DESCRIPTION
19	GILA	34° 20'	111° 5'	0.75	ROUTE 160, AT KOHLS RANCH; dark forest soil
20	GILA	33° 49'	110° 27'	0.75	ROUTE 77, 6 MILES NORTH OF SALT RIVER CROSSING, NORTHEAST OF GLOBE; dark forest soil
21	GRAHAM	32° 26'	109° 21'	0.75	8 MILES, NORTHWEST OF BOWIE; alluvial soil
22	GRAHAM	32° 45'	109° 30'	0.75	8 MILES, SOUTHEAST OF SOLOMON; alluvial soil
23	GRAHAM	33° 8'	110° 8'	0.75	U.S. 70, AT BYLAS; arid light soil
24	GREENLEE	33° 22'	109° 17'	0.75	U.S. 666, 54 MILES NORTH OF CLIFTON IN WHITE MOUNTAINS; lithosol from basalt lava
25	MARICOPA	33° 52'	113° 11'	0.75	COUNTY RD. AT SUNRISE SPRINGS; sandy clay alluvium
26	MARICOPA	33° 25'	111° 50'	0.75	3200 EAST MAIL IN MESA; irrigated - alluvium
27	MARICOPA	32° 54'	112° 44'	0.75	ROUTE 85, 2 MILES SOUTH OF GILA BEND; soil not described
28	MOHAVE	36° 43'	113° 3'	0.75	10 MILES WEST OF KAIBAB; alluvial soil
29	MOHAVE	35° 12'	114° 5'	0.75	U.S. 93-466, 2 MILES WEST OF KINGMAN; light arid soil
30	MOHAVE	35° 47'	114° 31'	0.75	U.S. 93, 45 MILES NORTHWEST OF KINGMAN; arid light soil
31	MOHAVE	34° 20'	113° 10'	0.75	U.S. 93, 90 MILES SOUTHEAST OF KINGMAN; near Santa Maria R; soil not described
32	NAVAJO	36° 44'	110° 8'	0.75	U.S. 164-160, 6 MILES NORTHEAST OF KAYENTA; red drifting sand
33	NAVAJO	34° 25'	110° 37'	0.75	ROUTE 160, AT HEBER; arid light soil
34	NAVAJO	35° 2'	110° 37'	0.75	ROUTE 66-180, 5 MILES EAST OF WINSLOW; sandy soil
35	NAVAJO	35° 50'	110° 10'	0.1-0.5	ROUTE 364, 1 MILE WEST OF JEDDITO WASH; 1-6 in. depth; soil not described

Source: Boerngen and Shacklette, 1981.

TABLE A-1. LOCATION AND DESCRIPTION OF USGS SAMPLES OF SURFICIAL SOILS FROM ARIZONA

SAMPLE NO.	COUNTY	LATITUDE (Degree, Minute)	LONGITUDE (Degree, Minute)	DEPTH (Feet)	SITE AND SOIL DESCRIPTION
36	NAVAJO	35° 55'	110° 40'	0.1-0.5	ROUTE 264, 0.5 MILES WEST OF HOTEVILLA; 1-6 in. depth; soil not described
37	PIMA	32° 12'	112° 50'	0.75	ROUTE 85, AT ROWOOD, 1 MILE EAST OF AJO; soil not described
38	PIMA	32° 10'	112° 10'	0.75	ROUTE 86, 2 MILES WEST OF QUIJOTOA; soil not described
39	PIMA	32° 0'	111° 15'	0.75	ROUTE 86, 286 JUNCTION, ROBLES JUNCTION; soil not described
40	PINAL	32° 48'	111° 45'	0.75	1-10 and 108, 6 MILES SOUTH OF CASA GRANDE; sandy colluvium
41	PINAL	33° 18'	111° 5'	0.75	U.S. 60-70, WEST EDGE OF SUPERIOR; stony rough soil
42	SANTA CRUZ	31° 22'	110° 53'	0.75	ROUTE 82, 1 MILE NORTHEAST OF NOGALES; soil not described
43	YUMA	33° 55'	113° 25'	0.75	8 MILES NORTHEAST OF WENDEN; alluvial soil
44	YUMA	33° 3'	113° 24'	0.75	LOS PALOMAS RANCH NEAR HYDER, 25 MILES NORTH OF SENTINEL & INTERSTATE-8; sandy alluvium
45	YUMA	33° 40'	114° 14'	0.75	U.S. 95, 1 MILE SOUTH OF JUNCTION WITH INTERSTATE-10, NEAR QUARTZSITE; soil not described
46	YUMA	32° 53'	114° 30'	0.75	ROUTE 95, 24 MILES NORTH OF YUMA; soil not described
47	YUMA	32° 45'	113° 37'	0.75	INTERSTATE-8 AT MOHAWK PASS; soil not described

Source: Boerngen and Shacklette, 1981.

TABLE A-2. CONCENTRATIONS OF SELECTED METALS DETECTED IN USGS SAMPLES OF SURFICIAL SOILS FROM ARIZONA

Sample No.	CONCENTRATION in mg/kg																		
	Aluminum (Al)	Anti-mony (Sb)	Arsenic (As)	Barium (Ba)	Bery-llium (Be)	Cad-mium (Cd)	Chro-mium (Cr)	Cobalt (Co)	Copper (Cu)	Lead (Pb)	Mer-cury (Hg)	Molyb-denum (Mo)	Nickel (Ni)	Sele-nium (Se)	Sil-ver (Ag)	Thal-lium (Tl)	Ura-nium (U)	Vana-dium (V)	Zinc (Zn)
1	70,000	–	5.3	500	ND	–	20.0	10	20.0	15	0.09	ND	30	0.2	–	–	–	70	25
2	30,000	–	–	500	ND	–	30.0	7	10.0	15	–	ND	15	–	–	–	–	30	–
3	30,000	–	6.2	500	ND	–	30.0	7	30.0	15	0.06	ND	15	0.1	–	–	–	70	42
4	15,000	–	1.6	300	ND	–	7.0	<3	7.0	10	0.10	ND	7	0.1	–	–	–	15	25
5	30,000	–	8.5	500	ND	–	30.0	7	30.0	20	0.16	ND	15	0.1	–	–	–	70	50
6	50,000	–	4.3	700	ND	–	15.0	7	15.0	30	0.02	ND	7	0.1	–	–	–	70	50
7	30,000	–	7.1	300	ND	–	15.0	7	70.0	70	0.10	3	15	1.1	–	–	–	30	90
8	100,000	<1	2.3	1,500	ND	–	5.0	5	10.0	20	0.03	ND	ND	0.1	–	–	3.40	70	31
9	30,000	<1	2.0	500	ND	–	7.0	ND	10.0	10	0.02	ND	5	0.1	–	–	1.11	15	18
10	30,000	–	16.0	200	ND	–	30.0	7	30.0	20	0.14	ND	20	1.6	–	–	–	50	50
11	>100,000	–	65.0	700	ND	–	100.0	30	30.0	20	0.08	ND	50	0.3	–	–	–	100	100
12	>100,000	–	1.4	700	3.0	–	70.0	15	30.0	20	0.08	ND	70	0.3	–	–	–	70	100
13	20,000	–	–	200	ND	–	10.0	ND	7.0	15	–	ND	15	–	–	–	–	20	50
14	20,000	–	–	300	ND	–	100.0	5	10.0	20	–	ND	15	–	–	–	–	30	–
15	30,000	–	–	200	ND	–	50.0	7	10.0	15	–	ND	15	–	–	–	–	20	25
16	50,000	–	–	300	ND	–	150.0	10	20.0	20	–	ND	15	–	–	–	–	70	75
17	30,000	–	–	200	ND	–	20.0	ND	10.0	15	–	ND	10	–	–	–	–	20	–

Notes:

ND = Not detected

– = No data available.

Source: Boerngen and Shacklette, 1981.

TABLE A-2. CONCENTRATIONS OF SELECTED METALS DETECTED IN USGS SAMPLES OF SURFICIAL SOILS FROM ARIZONA
(Page 2 of 3)

Sample No.	CONCENTRATION in mg/kg																		
	Aluminum (Al)	Antimony (Sb)	Arsenic (As)	Barium (Ba)	Beryllium (Be)	Cadmium (Ca)	Chromium (Cr)	Cobalt (Co)	Copper (Cu)	Lead (Pb)	Mercury (Hg)	Molybdenum (Mo)	Nickel (Ni)	Selenium (Se)	Silver (Ag)	Thallium (Tl)	Uranium (U)	Vanadium (V)	Zinc (Zn)
18	30,000	--	9.8	500	ND	--	150.0	15	30.0	20	0.06	ND	50	0.5	--	--	--	150	95
19	30,000	--	6.2	200	ND	--	70.0	7	20.0	10	0.10	ND	30	0.2	--	--	--	50	50
20	30,000	--	8.3	200	1.5	--	100.0	10	20.0	15	0.05	ND	30	0.4	--	--	--	70	25
21	>100,000	--	7.6	700	ND	--	300.0	10	50.0	20	0.05	ND	30	0.1	--	--	--	70	60
22	70,000	--	4.7	500	ND	--	100.0	10	30.0	15	0.02	ND	20	0.2	--	--	--	100	60
23	70,000	--	7.4	700	ND	--	50.0	15	20.0	50	0.05	ND	30	0.4	--	--	--	100	50
24	70,000	--	5.2	1,000	ND	--	300.0	30	70.0	20	0.42	3	150	0.2	--	--	--	300	81
25	70,000	--	8.2	500	ND	--	100.0	10	50.0	15	0.05	ND	30	0.1	--	--	--	70	75
26	>100,000	--	6.5	700	ND	--	70.0	15	30.0	20	0.06	3	50	0.1	--	--	--	100	100
27	70,000	--	2.0	700	1.5	--	30.0	10	30.0	30	0.05	ND	15	0.1	--	--	--	70	60
28	70,000	--	7.5	300	ND	--	50.0	10	30.0	ND	0.04	ND	15	0.2	--	--	--	70	70
29	>100,000	--	5.7	1,000	3.0	--	200.0	20	30.0	20	0.06	3	150	0.2	--	--	--	150	100
30	70,000	<-1	8.6	700	3.0	--	70.0	15	30.0	30	0.03	ND	50	0.1	--	--	--	70	150
31	>100,000	<-1	6.9	500	5.0	--	50.0	15	30.0	50	0.57	ND	70	0.4	--	--	--	100	100
32	10,000	--	1.6	200	ND	--	10.0	ND	5.0	ND	0.01	ND	<5	0.2	--	--	1.13	10	12
33	30,000	--	7.0	300	ND	--	30.0	5	20.0	10	0.03	ND	15	0.8	--	--	--	30	25
34	50,000	--	6.3	700	ND	--	70.0	10	20.0	20	0.06	ND	20	0.2	--	--	--	70	25

Notes:

ND = Not detected
-- = No data available.

Source: Boerngen and Shacklette, 1981.

TABLE A-2. CONCENTRATIONS OF SELECTED METALS DETECTED IN USGS SAMPLES OF SURFICIAL SOILS FROM ARIZONA
(Page 3 of 3)

Sample No.	CONCENTRATION in mg/kg																		
	Aluminum (Al)	Anti-mony (Sb)	Arsenic (As)	Barium (Ba)	Bery-llium (Be)	Cad-mium (Ca)	Chro-mium (Cr)	Cobalt (Co)	Copper (Cu)	Lead (Pb)	Mer-cury (Hg)	Molyb-denum (Mo)	Nickel (Ni)	Sele-nium (Se)	Sil-ver (Ag)	Thal-lium (Tl)	Ura-nium (U)	Vana-dium (V)	Zinc (Zn)
35	30,000	--	--	500	ND	--	20.0	7	10.0	15	--	ND	10	--	--	--	--	30	25
36	50,000	--	--	500	ND	--	15.0	5	10.0	20	--	ND	10	--	--	--	--	30	50
37	30,000	--	4.9	700	ND	--	30.0	10	30.0	20	0.04	3	15	0.1	--	--	--	70	60
38	70,000	--	5.9	1,000	ND	--	30.0	15	70.0	70	0.06	3	15	0.1	--	--	--	70	70
39	50,000	<1	2.9	700	1.5	--	15.0	7	20.0	15	0.04	ND	10	0.1	--	--	--	70	50
40	100,000	<1	4.0	700	1.5	--	70.0	10	30.0	20	0.01	ND	30	0.1	--	--	2.37	150	68
41	>100,000	--	97.0	700	ND	--	50.0	10	30.0	100	0.48	ND	20	0.8	--	--	--	100	50
42	50,000	--	9.1	700	1.5	--	15.0	7	20.0	30	0.05	ND	15	0.1	--	--	--	70	80
43	>100,000	--	2.9	700	ND	--	70.0	20	30.0	15	0.03	ND	30	0.4	--	--	--	100	30
44	70,000	<1	2.7	1,000	1.5	--	50.0	7	7.0	20	0.03	ND	20	0.1	--	--	2.64	70	70
45	30,000	--	7.0	500	ND	--	15.0	7	30.0	20	0.16	ND	7	0.2	--	--	--	50	70
46	50,000	--	6.7	700	1.5	--	30.0	10	15.0	30	0.03	ND	15	0.1	--	--	--	70	70
47	30,000	--	9.2	700	ND	--	30.0	10	70.0	30	0.36	ND	15	0.2	--	--	--	70	70
Maximum	100,000	<1	97	1,500	5	--	300	30	200	100	0.57	3.0	150	1.6	--	--	3.4	300	150
Minimum	30,000	<1	1.4	200	ND	--	5	ND	5	ND	0.01	ND	ND	<0.1	--	--	1.1	10	12
Average	55,213	<1	9.8	565	0.52	--	61.3	9.7	30	23.4	0.10	3.0	27.5	0.30	--	--	2.1	71.3	62.1
Standard Deviation	28,246	0	17.2	269.7	1.01	--	66	6.3	30.5	20.7	0.13	2.8	30.5	0.26	--	--	1.0	46.4	34

Notes:

ND = Not detected
-- = No data available.

Source: Boerngen and Shacklette, 1981.

APPENDIX B

ADEQ SOIL SAMPLE ANALYTICAL RESULTS AND LOCATIONS

APPENDIX B. ADEQ SOIL SAMPLE ANALYTICAL RESULTS AND LOCATIONS

Appendix B consists of available background data on metals concentrations in soil samples. Information in this appendix was obtained from the ADEQ sources listed in Section 2.0. This database is comprised of two tables that are a compilation of data from several reports provided to the ADEQ. Table B-1 and B-2 contain the following information:

- o Table B-1 lists the location and source of each sample.
- o Table B-2 lists the concentrations in milligrams per kilogram (mg/kg) for each metal for each soil sample.

TABLE B-1. LOCATION AND SOURCE OF SOIL SAMPLING DATA OBTAINED FROM ADEQ RECORDS

SAMPLE NO.	COUNTY	LATITUDE (Degree, Minute)	LONGITUDE (Degree, Minute)	DEPTH	ADEQ GROUP	FACILITY/ SITE	FACILITY SITE SAMPLE ID NO.
48a	Pima	32° 10'	110° 50'	0.75	RCRA Compliance Unit	Olive Grove/Tucson	GB-1A
48b	Pima	32° 10'	110° 50'	0.75	RCRA Compliance Unit	Olive Grove/Tucson	GB-1B
48c	Pima	32° 10'	110° 50'	0.75	RCRA Compliance Unit	Olive Grove/Tucson	GB-1C
48d	Pima	32° 10'	110° 50'	0.75	RCRA Compliance Unit	Olive Grove/Tucson	GB-1D
48e	Pima	32° 10'	110° 50'	0.75	RCRA Compliance Unit	Olive Grove/Tucson	GB-1E
48f	Pima	32° 10'	110° 50'	0.75	RCRA Compliance Unit	Olive Grove/Tucson	GB-1F
49	Pima	32° 16'	110° 55'	Surface	RCRA Compliance Unit	Arizona Gear/Tucson	B-3
50	Pima	32° 15'	110° 57'	0.25	Remedial Projects Unit	Chrome Co./Tucson	HS-4
51	Pima	32° 12'	110° 56'	1	Groundwater Hydrology Section	Pacific Fruit Express/Tucson	Background
52	Maricopa	33° 25'	111° 51'	3	Site Discovery and Hazard Evaluation unit	Metal Refinishers/ Mesa	Background
53	Maricopa	33° 27'	112° 02'	5	Remedial Projects Unit	Frazee/Deer-O Paint & Wallcoverings/Phoenix	S-1
54	Maricopa	33° 29'	111° 58'	65-70	Site Discovery and Hazard Evaluation Unit	Motorola/Phoenix	Background
55	Maricopa	33° 25'	111° 59'	Surface	Remedial Projects Unit	ABS Metallurgical Processors, Inc./Phoenix	11
56a	Maricopa	33° 25'	112° 22'	0.3	Site Discovery and Hazard Evaluation Unit	Phoenix-Goodyear Airport RI/FS	0110
56b	Maricopa	33° 25'	112° 22'	0.75	Site Discovery and Hazard Evaluation Unit	Phoenix-Goodyear Airport RI/FS	0110
56c	Maricopa	33° 25'	112° 22'	1	Site Discovery and Hazard Evaluation Unit	Phoenix-Goodyear Airport RI/FS	0110
56d	Maricopa	33° 25'	112° 22'	2.0	Site Discovery and Hazard Evaluation Unit	Phoenix-Goodyear Airport RI/FS	0110
56e	Maricopa	33° 25'	112° 22'	3	Site Discovery and Hazard Evaluation Unit	Phoenix-Goodyear Airport RI/FS	0110
56f	Maricopa	33° 25'	112° 22'	4.5	Site Discovery and Hazard Evaluation Unit	Phoenix-Goodyear Airport RI/FS	0110
56g	Maricopa	33° 25'	112° 22'	6	Site Discovery and Hazard Evaluation Unit	Phoenix-Goodyear Airport RI/FS	0110
56h	Maricopa	33° 25'	112° 22'	9	Site Discovery and Hazard Evaluation Unit	Phoenix-Goodyear Airport RI/FS	0110
57a	Maricopa	33° 25'	112° 22'	0.3	Site Discovery and Hazard Evaluation Unit	Phoenix-Goodyear Airport RI/FS	0120
57b	Maricopa	33° 25'	112° 22'	0.75	Site Discovery and Hazard Evaluation Unit	Phoenix-Goodyear Airport RI/FS	0120
57c	Maricopa	33° 25'	112° 22'	1	Site Discovery and Hazard Evaluation Unit	Phoenix-Goodyear Airport RI/FS	0120
57d	Maricopa	33° 25'	112° 22'	2.0	Site Discovery and Hazard Evaluation Unit	Phoenix-Goodyear Airport RI/FS	0120
57e	Maricopa	33° 25'	112° 22'	3	Site Discovery and Hazard Evaluation Unit	Phoenix-Goodyear Airport RI/FS	0120
57f	Maricopa	33° 25'	112° 22'	4.5	Site Discovery and Hazard Evaluation Unit	Phoenix-Goodyear Airport RI/FS	0120
57g	Maricopa	33° 25'	112° 22'	6	Site Discovery and Hazard Evaluation Unit	Phoenix-Goodyear Airport RI/FS	0120
57h	Maricopa	33° 25'	112° 22'	9	Site Discovery and Hazard Evaluation Unit	Phoenix-Goodyear Airport RI/FS	0120

TABLE B-1. LOCATION AND SOURCE OF SOIL SAMPLING DATA OBTAINED FROM ADEQ RECORDS

SAMPLE NO.	COUNTY	LATITUDE (Degree, Minute)	LONGITUDE (Degree, Minute)	DEPTH	ADEQ GROUP	FACILITY/ SITE	FACILITY SITE SAMPLE ID NO.
58a	Maricopa	33° 25'	112° 22'	0.3	Site Discovery and Hazard Evaluation Unit	Phoenix-Goodyear Airport RI/FS	0210
58b	Maricopa	33° 25'	112° 22'	0.75	Site Discovery and Hazard Evaluation Unit	Phoenix-Goodyear Airport RI/FS	0210
58c	Maricopa	33° 25'	112° 22'	1	Site Discovery and Hazard Evaluation Unit	Phoenix-Goodyear Airport RI/FS	0210
58d	Maricopa	33° 25'	112° 22'	2.0	Site Discovery and Hazard Evaluation Unit	Phoenix-Goodyear Airport RI/FS	0210
58e	Maricopa	33° 25'	112° 22'	3	Site Discovery and Hazard Evaluation Unit	Phoenix-Goodyear Airport RI/FS	0210
58f	Maricopa	33° 25'	112° 22'	4.5	Site Discovery and Hazard Evaluation Unit	Phoenix-Goodyear Airport RI/FS	0210
58g	Maricopa	33° 25'	112° 22'	6	Site Discovery and Hazard Evaluation Unit	Phoenix-Goodyear Airport RI/FS	0210
58h	Maricopa	33° 25'	112° 22'	9	Site Discovery and Hazard Evaluation Unit	Phoenix-Goodyear Airport RI/FS	0210
59a	Maricopa	33° 25'	112° 22'	0.3	Site Discovery and Hazard Evaluation Unit	Phoenix-Goodyear Airport RI/FS	0220
59b	Maricopa	33° 25'	112° 22'	0.75	Site Discovery and Hazard Evaluation Unit	Phoenix-Goodyear Airport RI/FS	0220
59c	Maricopa	33° 25'	112° 22'	1	Site Discovery and Hazard Evaluation Unit	Phoenix-Goodyear Airport RI/FS	0220
59d	Maricopa	33° 25'	112° 22'	2.0	Site Discovery and Hazard Evaluation Unit	Phoenix-Goodyear Airport RI/FS	0220
59e	Maricopa	33° 25'	112° 22'	3	Site Discovery and Hazard Evaluation Unit	Phoenix-Goodyear Airport RI/FS	0220
59f	Maricopa	33° 25'	112° 22'	4.5	Site Discovery and Hazard Evaluation Unit	Phoenix-Goodyear Airport RI/FS	0220
59g	Maricopa	33° 25'	112° 22'	6	Site Discovery and Hazard Evaluation Unit	Phoenix-Goodyear Airport RI/FS	0220
59h	Maricopa	33° 25'	112° 22'	9	Site Discovery and Hazard Evaluation Unit	Phoenix-Goodyear Airport RI/FS	0220
60a	Maricopa	33° 25'	112° 22'	0.3	Site Discovery and Hazard Evaluation Unit	Phoenix-Goodyear Airport RI/FS	0230
60b	Maricopa	33° 25'	112° 22'	0.75	Site Discovery and Hazard Evaluation Unit	Phoenix-Goodyear Airport RI/FS	0230
60c	Maricopa	33° 25'	112° 22'	1	Site Discovery and Hazard Evaluation Unit	Phoenix-Goodyear Airport RI/FS	0230
60d	Maricopa	33° 25'	112° 22'	2.0	Site Discovery and Hazard Evaluation Unit	Phoenix-Goodyear Airport RI/FS	0230
60e	Maricopa	33° 25'	112° 22'	3	Site Discovery and Hazard Evaluation Unit	Phoenix-Goodyear Airport RI/FS	0230
60f	Maricopa	33° 25'	112° 22'	4.5	Site Discovery and Hazard Evaluation Unit	Phoenix-Goodyear Airport RI/FS	0230
60g	Maricopa	33° 25'	112° 22'	6	Site Discovery and Hazard Evaluation Unit	Phoenix-Goodyear Airport RI/FS	0230
60h	Maricopa	33° 25'	112° 22'	9	Site Discovery and Hazard Evaluation Unit	Phoenix-Goodyear Airport RI/FS	0230

TABLE B-1. LOCATION AND SOURCE OF SOIL SAMPLING DATA OBTAINED FROM ADEQ RECORDS

SAMPLE NO.	COUNTY	LATITUDE (Degree, Minute)	LONGITUDE (Degree, Minute)	DEPTH	ADEQ GROUP	FACILITY/ SITE	FACILITY SITE SAMPLE ID NO.
61a	Maricopa	33° 25'	112° 22'	0.3	Site Discovery and Hazard Evaluation Unit	Phoenix-Goodyear Airport RI/FS	0320
61b	Maricopa	33° 25'	112° 22'	0.75	Site Discovery and Hazard Evaluation Unit	Phoenix-Goodyear Airport RI/FS	0320
61c	Maricopa	33° 25'	112° 22'	1	Site Discovery and Hazard Evaluation Unit	Phoenix-Goodyear Airport RI/FS	0320
61d	Maricopa	33° 25'	112° 22'	2.0	Site Discovery and Hazard Evaluation Unit	Phoenix-Goodyear Airport RI/FS	0320
61e	Maricopa	33° 25'	112° 22'	3	Site Discovery and Hazard Evaluation Unit	Phoenix-Goodyear Airport RI/FS	0320
61f	Maricopa	33° 25'	112° 22'	4.5	Site Discovery and Hazard Evaluation Unit	Phoenix-Goodyear Airport RI/FS	0320
61g	Maricopa	33° 25'	112° 22'	6	Site Discovery and Hazard Evaluation Unit	Phoenix-Goodyear Airport RI/FS	0320
61h	Maricopa	33° 25'	112° 22'	9	Site Discovery and Hazard Evaluation Unit	Phoenix-Goodyear Airport RI/FS	0320
62	Pinal	32° 56'	110° 5'	Surface	RCRA Compliance Unit	Hexcel Disposal/Casa Grande	Background

TABLE B-2. CONCENTRATIONS OF SELECTED METALS DETECTED IN ADEQ SAMPLES

(Page 1 of 3)

Sample No.	CONCENTRATION in mg/kg																		
	Aluminum (Al)	Antimony (Sb)	Arsenic (As)	Barium (Ba)	Beryllium (Be)	Cadmium (Cd)	Chromium (Cr)	Cobalt (Co)	Copper (Cu)	Lead (Pb)	Mercury (Hg)	Molybdenum (Mo)	Nickel (Ni)	Selenium (Se)	Silver (Ag)	Thallium (Tl)	Uranium (U)	Vanadium (V)	Zinc (Zn)
48a	7,400	--	--	--	--	ND	7.2	--	10	TR	--	--	--	--	--	--	--	--	21
48b	8,800	--	--	--	--	ND	7.7	--	10	ND	--	--	--	--	--	--	--	--	21
48c	7,100	--	--	--	--	ND	6.9	--	9.0	TR	--	--	--	--	--	--	--	--	18
48d	12,000	--	--	--	--	ND	8.8	--	11	ND	--	--	--	--	--	--	--	--	23
48e	9,400	--	--	--	--	ND	2.3	--	9.7	ND	--	--	--	--	--	--	--	--	23
48f	6,200	--	--	--	--	ND	6.0	--	8.7	TR	--	--	--	--	--	--	--	--	21
49	--	--	24	230	--	<0.5	14	--	--	9.4	0.25	--	--	<0.5	--	--	--	--	--
50	--	--	--	--	--	<0.5	5.45	--	--	8.91	--	--	19.3	--	--	--	--	--	--
51	15,800	3.8	3.1	72.6	0.96	0.81	11.3	--	17.1	24.5	0.13	--	9.2	0.96	0.70	0.47	--	23.8	--
52	--	--	--	--	--	--	--	--	9.6	--	--	--	--	--	--	--	--	--	--
53	--	<1	6	--	0.30	1.9	19	--	15	5	<1	--	21	<1	0.8	<1	--	--	27
54	--	<0.4	--	--	<2.0	<0.5	9.0	--	6.0	5.3	<0.01	--	14	<0.4	<0.05	--	--	<0.2	15
55	--	--	--	--	--	--	29	--	--	--	--	--	--	--	--	--	--	--	--
56a	8,822	--	8.6	130	--	0.4	15	--	13	9.5	ND	--	12	--	--	--	--	--	32
56b	8,401	--	9.5	158	--	0.3	16	--	11	9.3	ND	--	12	--	--	--	--	--	30
56c	8,056	--	8.6	158	--	0.6	16	--	11	8.0	ND	--	12	--	--	--	--	--	33
56d	8,236	--	8.7	218	--	0.5	14	--	10	5.7	ND	--	10	--	--	--	--	--	25
56e	--	--	--	--	--	--	12	--	--	--	--	--	--	--	--	--	--	--	--
56f	--	--	--	--	--	--	14	--	--	--	--	--	--	--	--	--	--	--	--
56g	--	--	--	--	--	--	16	--	--	--	--	--	--	--	--	--	--	--	--
56h	--	--	--	--	--	--	12	--	--	--	--	--	--	--	--	--	--	--	--
57a	15,447	--	6.1	168	--	1.2	34	--	24	11.5	ND	--	19	--	--	--	--	--	63
57b	13,832	--	6.0	164	--	1.0	36	--	23	8.7	ND	--	17	--	--	--	--	--	60
57c	16,067	--	6.5	169	--	1.7	34	--	25	11.2	ND	--	20	--	--	--	--	--	81
57d	16,817	--	6.5	169	--	0.6	24	--	23	10.4	ND	--	20	--	--	--	--	--	54
57e	--	--	--	--	--	--	25	--	--	--	--	--	--	--	--	--	--	--	--
57f	--	--	--	--	--	--	22	--	--	--	--	--	--	--	--	--	--	--	--
57g	--	--	--	--	--	--	14	--	--	--	--	--	--	--	--	--	--	--	--
57h	--	--	--	--	--	--	3	--	--	--	--	--	--	--	--	--	--	--	--

Notes:

ND = Not detected

-- = No data available.

Source: Boerngen and Shacklette, 1981.

TABLE B-2. CONCENTRATIONS OF SELECTED METALS DETECTED IN ADEQ SAMPLES

(Page 2 of 3)

Sample No.	CONCENTRATION in mg/kg																		
	Aluminum (Al)	Antimony (Sb)	Arsenic (As)	Barium (Ba)	Beryllium (Be)	Cadmium (Cd)	Chromium (Cr)	Cobalt (Co)	Copper (Cu)	Lead (Pb)	Mercury (Hg)	Molybdenum (Mo)	Nickel (Ni)	Selenium (Se)	Silver (Ag)	Thallium (Tl)	Uranium (U)	Vanadium (V)	Zinc (Zn)
58a	9,381	--	9.5	152	--	--	16	--	15	8.2	ND	--	15	--	--	--	--	--	37
58b	7,963	--	9.2	154	--	--	14	--	14	6.6	ND	--	14	--	--	--	--	--	34
58c	13,147	--	8.7	176	--	--	17	--	16	6.8	ND	--	13	--	--	--	--	--	36
58d	9,748	--	10.7	178	--	--	17	--	15	5.5	ND	--	15	--	--	--	--	--	34
58e	--	--	--	--	--	--	13	--	--	--	--	--	--	--	--	--	--	--	--
58f	--	--	--	--	--	--	18	--	--	--	--	--	--	--	--	--	--	--	--
58g	--	--	--	--	--	--	22	--	--	--	--	--	--	--	--	--	--	--	--
58h	--	--	--	--	--	--	30	--	--	--	--	--	--	--	--	--	--	--	--
59a	9,375	--	10.1	151	--	0.4	16	--	20	11.1	ND	--	19	--	--	--	--	--	43
59b	10,192	--	9.9	172	--	ND	16	--	19	6.6	ND	--	19	--	--	--	--	--	40
59c	11,315	--	9.8	173	--	0.4	16	--	20	6.9	ND	--	20	--	--	--	--	--	42
59d	9,420	--	8.1	163	--	0.4	15	--	19	6.2	ND	--	18	--	--	--	--	--	41
59e	--	--	--	--	--	--	16	--	--	--	--	--	--	--	--	--	--	--	--
59f	--	--	--	--	--	--	18	--	--	--	--	--	--	--	--	--	--	--	--
59g	--	--	--	--	--	--	15	--	--	--	--	--	--	--	--	--	--	--	--
59h	--	--	--	--	--	--	13	--	--	--	--	--	--	--	--	--	--	--	--
60a	8,558	--	16.1	151	0.96	0.3	28	--	18	9.5	ND	--	18	--	--	--	--	--	39
60b	9,130	--	12.1	121	--	0.2	19	--	18	6.9	ND	--	18	--	--	--	--	--	35
60c	15,328	--	9.4	156	--	0.4	29	--	27	8.9	ND	--	26	--	--	--	--	--	62
60d	12,685	--	9.6	116	0.30	0.4	22	--	23	--	ND	--	23	--	--	--	--	--	51
60e	--	--	--	--	--	--	22	--	--	--	--	--	--	--	--	--	--	--	--
60f	--	--	--	--	--	--	23	--	--	--	--	--	--	--	--	--	--	--	--
60g	--	--	--	--	--	--	21	--	--	--	--	--	--	--	--	--	--	--	--
60h	--	--	--	--	--	--	16	--	--	--	--	--	--	--	--	--	--	--	--
61a	13,679	--	10.4	197	<2.0	0.6	21	--	27	17.6	ND	--	27	--	--	--	--	--	54
61b	11,452	--	9.2	174	--	0.6	18	--	20	9.0	ND	--	25	--	--	--	--	--	47
61c	11,423	--	8.4	166	--	0.2	21	--	24	9.8	ND	--	28	--	--	--	--	--	51
61d	12,895	--	8.4	158	--	0.2	20	--	24	11.6	ND	--	27	--	--	--	--	--	52
61e	--	--	--	--	--	--	18	--	--	--	--	--	--	--	--	--	--	--	--
61f	--	--	--	--	--	--	21	--	--	--	--	--	--	--	--	--	--	--	--
61g	--	--	--	--	--	--	18	--	--	--	--	--	--	--	--	--	--	--	--
61h	--	--	--	--	--	--	11	--	--	--	--	--	--	--	--	--	--	--	--
62	--	--	--	--	--	--	--	6.0	--	--	--	--	--	--	--	--	--	--	--

Notes:

ND = Not detected

-- = No data available.

TABLE B-2. CONCENTRATIONS OF SELECTED METALS DETECTED IN ADEQ SAMPLES
(Page 3 of 3)

Sample No.	CONCENTRATION in mg/kg																		
	Aluminum (Al)	Antimony (Sb)	Arsenic (As)	Barium (Ba)	Beryllium (Be)	Cadmium (Ca)	Chromium (Cr)	Cobalt (Co)	Copper (Cu)	Lead (Pb)	Mercury (Hg)	Molybdenium (Mo)	Nickel (Ni)	Selenium (Se)	Silver (Ag)	Thallium (Tl)	Uranium (U)	Vanadium (V)	Zinc (Zn)
Maximum	16,827	3.8	24	230	2.0	1.7	34	–	27	24.5	0.25	–	28	1.0	0.8	<1.0	–	23.8	81
Minimum	6,200	<0.4	3.1	72.6	0.3	ND	5.4	–	6.0	ND	ND	–	9.2	<0.4	<0.05	0.5	–	<0.2	15
Average	10,654	1.7	9.4	161.3	1.1	0.4	17.5	–	16.6	7.7	0.05	–	18.2	0.6	0.5	0.7	–	12	38.9
Standard Deviaiton	2,859	1.8	3.8	30.5	0.9	0.4	7.0	–	5.9	4.8	0.2	–	5.3	0.3	0.4	0.4	–	16.7	16.4

Notes:

ND = Not detected

– = No data available.

Source: Boerngen and Shacklette, 1981.

APPENDIX C

SELECTED METALLIC MINERAL DISTRICTS IN ARIZONA

APPENDIX C. SELECTED METALLIC MINERAL DISTRICTS IN ARIZONA

Appendix C contains a compilation of data from selected metallic mineral districts in Arizona. These districts are within the surface-water drainage basins that converge in the Phoenix and Tucson areas. The source for this material comes from the Arizona Bureau of Geology and Mineral Technology (Keith, et al., 1983).

Tables C-1 and C-2 contain the following information:

- o Table C-1 lists the mineral districts within the surface-water drainage basins for Phoenix and Tucson giving location, description, and District No. as shown on Plate 1.
- o Table C-2 gives the percentages of metals within each district.

TABLE C-1. LOCATION AND DESCRIPTION OF SELECTED METALLIC MINERAL DISTRICTS IN ARIZONA
(Page 1 of 2)

District No. (Plate 1)	Mineral District	County	Latitude (Degree, Minute)	Longitude (Degree, Minute)	Deposit Description
D1	Amole	Pima	32° 15′	111° 07′	lead, zinc, silver
L1	Apache Iron	Navajo	34° 09′	110° 40′	iron
H1	Bickle	Maricopa	33° 49′	111° 47′	tungsten
B1	Bloody Basin	Yavapai	34° 09′	111° 52′	copper, w/o gold
F1	Blue Bird	Santa Cruz	31° 26′	110° 32′	manganese
A1	Bradford	Santa Cruz	31° 28′	110° 50′	copper porphyry
J1	Bronco Creek	Maricopa	33° 51′	111° 51′	copper, gold, silver
H2	Camp Verde	Yavapai	34° 28′	111° 53′	tungsten
K9	Cardinal Avenue	Pima	32° 06′	111° 02′	uranium
A2	Catalina	Pima	32° 18′	110° 52′	copper porphyry
C1	Cave Creek	Maricopa	33° 49′	111° 52′	gold, w/o copper
H3	Cave Creek	Santa Cruz	31° 49′	110° 47′	copper porphyry
C2	Cherry Creek	Yavapai	34° 33′	112° 03′	gold, w/o copper
K1	Ciebcue	Navajo	34° 02′	110° 28′	uranium
A4	Copper Basin	Yavapai	34° 29′	112° 35′	copper porphyry
A21	Cuprite	Pima	31° 54′	110° 39′	copper porphyry
K8	Duranium	Santa Cruz	31° 36′	110° 56′	uranium
D2	Empire	Pima	31° 60′	110° 36′	lead, zinc, silver
K2	Fossil Creek	Yavapai	34° 27′	111° 35′	uranium
H4	Four Peaks	Gila-Maricopa	33° 44′	111° 21′	tungsten
F5	Giant Cactus	Gila	33° 30′	110° 31′	manganese
A5	Globe Hills	Gila	35° 23′	110° 45′	copper porphyry
C3	Goldfield	Pinal-Maricopa	33° 36′	111° 28′	gold, w/o copper
J2	Grays Gluch	Maricopa	33° 57′	111° 54′	copper, gold, silver
D3	Greaterville	Pima	31° 52′	110° 44′	lead, zinc, silver
B3	Green Valley	Gila	34° 15′	111° 20′	copper, w/o gold
A6	Harshaw	Santa Cruz	31° 36′	110° 43′	copper porphyry
D4	Hartford	Cochise	31° 27′	110° 44′	lead, zinc, silver, veins
A7	Helvetia-Rosemont	Pima	31° 23′	110° 21′	copper porphyry
D5	Ivanhoe	Santa Cruz	31° 40′	110° 47′	lead, zinc, silver
A20	Jackson	Pima	31° 31′	110° 48′	lead, zinc, silver, veins
D7	Johnson & Hayden	Coconino	35° 39′	115° 0′	lead, silver, zinc
C4	Keystone	Pima	31° 50′	111° 13′	gold, w/o copper
F2	La McKoy	Yavapai	34° 05′	111° 37′	manganese
K3	Lime Creek	Maricopa	33° 57′	111° 44′	uranium
F3	Long Valley	Coconino	34° 33′	111° 19′	manganese
E1	Magazine	Maricopa	33° 58′	111° 49′	silver, w/o lead
D15	Mansfield	Santa cruz	33° 58′	111° 49′	lead, zinc, silver
G2	Mazatzal Mountains	Maricopa-Gila	33° 54′	111° 24′	mercury
B5	McDowell	Maricopa	33° 36′	111° 45′	copper, w/o gold
A7	Miami-Inspiration	Gila	33° 22′	110° 52′	copper porphyry
C5	Mineral Point	Yavapai	34° 38′	112° 16′	gold, w/o copper
C6	Nogales	Santa Cruz	31° 30′	110° 54′	gold, w/o copper

Source: Keith, Gest, DeWitt, Toll and Everson, 1983.

TABLE C-1. LOCATION AND DESCRIPTION OF SELECTED METALLIC MINERAL DISTRICTS IN ARIZONA
(Page 2 of 2)

ict No. (e 1)	Mineral District	County	Latitude (Degree, Minute)	Longitude (Degree, Minute)	Deposit Description
	Old Baldy	Pima-Santa Cruz	31° 38′	110° 52′	lead,zinc, silver
	Pajarito	Santa Cruz	31° 18′	110° 54′	lead, zinc, silver
8	Palmetto	Santa Cruz	31° 24′	110° 45′	copper porphyry
5	Parker Canyon	Santa Cruz	31° 22′	110° 28′	lead, zinc, silver
	Patagonia	Santa Cruz	31° 21′	110° 45′	copper porphyry
	Phoenix Mountains	Maricopa	35° 31′	112° 00′	mercury
A10	Pima	Pima	31° 56′	111° 04′	copper porphyry
A11	Pinal Mountains	Gila	33° 15′	110° 48′	copper porphyry
12	Pioneer	Pinal	33° 17′	110° 05′	copper porphyry
	Pittsburg-Tonto	Gila	33° 58′	111° 17′	copper, gold, silver
B6	Polk	Gila	34° 08′	111° 31′	copper, w/o gold
14	Pranty's Cabin	Gila	34° 02′	111° 13′	copper, gold, silver
7	Prescott	Yavapai	34° 30′	112° 23′	copper, w/o gold
4	Promontory Butte	Gila	33° 49′	111° 15′	uranium
K5	Pumpkin Center	Gila	31° 17′	110° 42′	uranium
A13	Querces	Santa Cruz	31° 17′	110° 42′	copper porphyry
A14	Quien Sabe	Pima	32° 08′	111° 02′	copper porphyry
F6	Ramsdell	Gila	33° 45′	110° 41′	manganese
D10	Red Rock	Santa Cruz	31° 28′	110° 35′	lead, zinc, silver
A15	Richmond Basin	Gila	33° 29′	110° 45′	copper porphyry
B7	Rincon	Pima	32° 01′	110° 37′	copper, w/o gold
C8	Roosevelt	Gila	33° 42′	111° 10′	gold, w/o copper
F4	Rye Creek	Gila	34° 05′	111° 18′	manganese
D11	San Cayetano	Santa Cruz	31° 28′	110° 57′	lead, zinc, silver
A16	Saginaw Hill	Pima	32° 06′	111° 02′	copper porphyry
D12	Salero	Santa Cruz	31° 33′	110° 50′	lead, zinc, silver
C9	Salt River Mountain	Maricopa	33° 17′	112° 03′	gold, w/o copper
K6	Salt River	Gila	33° 47′	110° 33′	uranium
L2	Seligman Iron	Yavapai	35° 06′	112° 52′	iron
E2	Shea	Yavapai	34° 38′	112° 05′	silver, w/o lead
K7	Sierra Ancha	Gila	33° 49′	110° 59′	uranium
C10	Spring Creek	Gila	34° 03′	111° 04′	gold, w/o lead
A17	Squaw Peak	Yavapai	34° 29′	111° 50′	copper porphyry
A18	Summit	Gila-Pinal	33° 18′	111° 00′	copper porphyry
F7	Sunset	Gila	33° 49′	111° 01′	manganese
C11	Thumb Butte	Yavapai	34° 33′	112° 32′	gold, w/o copper
D13	Tyndall	Santa Cruz	31° 38′	110° 54′	lead, zinc, silver
J5	Verde	Yavapai	34° 33′	112° 06′	copper, cold, silver
H5	Wagner	Gila	33° 32′	110° 59′	tungsten
A19	Washington Camp	Santa Cruz	31° 20′	110° 40′	copper porphyry
C12	Winifred	Maricopa	33° 37′	112° 02′	gold, w/o copper
D14	Wrightson	Santa Cruz	31° 37′	110° 49′	lead, zinc, silver

Source: Keith, Gest, DeWitt, Toll and Everson, 1983.

TABLE C-2. PERCENTAGES OF PRECIOUS METALS EXTRACTED FROM MINED MATERIALS FOR SELECTED MINERAL DISTRICTS IN ARIZONA
(Page 1 of 4)

District No. (Plate 1)	Copper (Cu)	Lead (Pb)	Zinc (Zn)	Molyb-denum (Mo)	Silver (Ag)	Uranium (U)	Vanadium (V)	Other Metals
D1	35.6%	58.8%	1.75%	4.2%	<1%	–	–	Gold (Ag) <½%
L1	–	–	–	–	–	–	–	Iron (Fe) 100%
H1	–	–	–	–	–	0.2%	–	Tungsten (W) 99.8%
B1	99.8%	–	–	–	0.2%	–	–	–
F1	–	–	–	–	–	–	–	Manganese (Mn) 100%
A1	91.6%	8.3%	–	–	.1%	–	–	–
J1	99.9%	–	–	–	0.03%			Gold (Ag) <0.5%
H2	–	–	–	–	–	–	–	Tungsten (W) 100%
K9	–	–	–	–	–	100%	–	–
A2	99.9%	<½%	–	–	–	–	–	–
C1	24.5%	<½%	–	–	<1%	–	–	Tungsten (W) 75%, gold (Ag) <½%
H3	97.62%	<1%	–	–	1.6%	–	–	Gold (Ag) <½%
C2	97.06%	<1%	–	–	1.5%	–	–	Gold (Ag) <½%
A4	91.1%	2.4%	6.5%	Reserves	<½%	–	–	Gold (Ag) <½%
K1	–	–	–	–	–	100%	–	Gold (Ag) <1%
A21	99.6%	–	–	–	–	–	–	–
K8					–	100%	–	Tungsten (W) 3.4%
D2	2.3%	94.2%	2.1%	0.3%	1%	–	–	Gold (Ag) <½%, other <1%
K2	–	–	–	–	–	–	–	–
H4	–	–	–	–	–	–	–	Tungsten 100%
F5	–	–	–	–	–	–	–	Manganese 8.5%
A5	99.6%	0.3%	<½%	–	0.5%	–	–	Gold (Ag) <½%
C3	96.3%	–	–	–	1.7%	–	–	Gold (Ag) 2%
J2	<½%	–	<½%	–	<½%	–	–	Gold (Ag) <½%
D3	1%	97%	1.7%	–	<½%	–	–	Gold (Ag) <½%
B3	99.5%	–	–	–	<½%	–	–	Gold (Ag) <½%
A6	1.3%	34.4%	43.8%	–	<½%	–	–	Manganese 20.4%, Gold <½%
D4	8.3%	54.7%	34.2%	–	<½%	–	–	Manganese 1.3%
A7	96%	<½%	2.9%	<½%	<½%	–	–	–

Source: Keith, et al., 1983.

TABLE C-2. PERCENTAGES OF PRECIOUS METALS EXTRACTED FROM MINED MATERIALS FOR SELECTED MINERAL DISTRICTS IN ARIZONA
(Page 2 of 4)

District No. (Plate 1)	Copper (Cu)	Lead (Pb)	Zinc (Zn)	Molyb-denum (Mo)	Silver (Ag)	Uranium (U)	Vanadium (V)	Other Metals
D5	12.8%	54.3%	--	--	<1%	--	--	Gold Aol <½%, Manganese (Mn) 32.4%
A20	97%	--	--	--	2.6%	--	--	--
D7	--	--	--	--	--	--	--	Manganese 100%
C4	10%	82%	7%	--	<1%	--	--	Gold <½%
F2	--	--	--	--	--	--	--	Manganese 100%
K3	--	--	--	--	--	100%	--	--
F3	--	--	--	--	--	--	--	Manganese 100%
E1	99.2%	--	--	--	<1%	--	--	--
D15	12.6%	87.1%	--	--	<½%	--	--	Gold <½%
G2	16.8%	82.4%	--	--	<1%	--	--	Gold <½%, Mercury (Hg)
B5	98.3%	--	--	--	1.6%	--	--	Gold <½%
A7	97.9%	<½%	<½%	1.9%	<½%	--	--	Gold <½%
C5	96%	--	--	--	2.3%	--	--	Gold 1.7%
C6	19.1%	--	--	--	<½%	--	--	Gold <½%, Tungsten 80.5%
D8	<½%	<½%	<½%	--	<½%	--	--	Gold
D16	2.2%	76.8%	<½%	--	1%	<½%	<½%	Gold <½%, Other 20%
A8	11.2%	57%	31.5%	--	<½%	--	--	Gold <½%
D9	28.1%	70.2%	--	--	1%	--	--	Gold <1%
A9	66.5%	33.1%	<½%	--	<½%	--	--	Gold <½%
G1	89.8%	--	--	--	--	--	--	Gold 10.2%, Mercury (Hg)
A10	94.2%	<1%	1.5%	3.3%	<½%	Reserves	--	Gold <½%, Tungsten <½%
A11	55.6%	42.4%	--	--	2.0%	--	--	Gold <½%
A12	92.0%	<½%	3.0%	--	<½%	--	--	Manganese 4.8%
J3	83.3%	16.7%	--	--	--	--	--	--
B6	100%	--	--	--	--	--	--	--
J4	<½%	--	--	--	<½%	--	--	Gold <½%
B7	99.9%	--	--	--	<½%	<½%	--	Gold <½%
K4	--	--	--	--	--	<½%	--	--
K5	--	--	--	--	--	--	--	--

Source: Keith, et al., 1983.

TABLE C-2. PERCENTAGES OF PRECIOUS METALS EXTRACTED FROM MINED MATERIALS FOR SELECTED MINERAL DISTRICTS IN ARIZONA

(Page 3 of 4)

District No. (Plate 1)	Copper (Cu)	Lead (Pb)	Zinc (Zn)	Molybdenum (Mo)	Silver (Ag)	Uranium (U)	Vanadium (V)	Other Metals
A13	99.9%	–	–	–	<½%	–	–	Gold <½%
A14	96.5%	3.4%	–	–	<½%	–	–	Gold <½%
F6	–	–	–	–	–	–	–	Manganese 100%
D10	44.2%	48.7%	6.6%	–	<½%	–	–	Gold <½%
A15	16.7%	11.1%	–	–	5.6%	–	–	Gold <½%, 66% Manganese
B7	92.7%	7.1%	–	–	<½%	–	–	Gold <½%
C8	–	–	–	–	–	–	–	Gold <½%
F4	–	–	–	–	–	–	–	Gold 100%
D11	<½%	<½%	<½%	–	<½%	–	–	Gold 1.7%
A16	31.0%	20.9%	46.7%	–	1.4%	–	–	Gold <½%
D12	11.1%	85.6%	2.9%	–	<½%	–	–	Gold <½%
C9	97.1%	–	–	–	1.2%	–	–	Gold 1.7%
K6	–	–	–	–	–	100%	–	–
L2	–	–	–	–	–	–	–	Iron (Fe)
E2	94.2%	–	–	–	5.7%	–	–	Gold <½%
K7	–	–	–	–	–	100%	–	–
C10	14.9%	44.8%	–	–	<½%	–	–	Gold <½%, Tungsten 40%
A17	24.6%	66.8%	<½%	7.8	<1%	–	–	Gold <½%
A18	99.9%	<½%	–	–	<½%	–	–	Gold <½%, Tungsten <½%
F7	–	–	–	–	–	–	–	Manganese 100%
C11	97.3%	–	–	–	<1%	–	–	Gold 2.0%
D13	<1%	67.9%	31.3%	–	<½%			Gold <½%

Source: Keith, et al., 1983.

TABLE C-2. PERCENTAGES OF PRECIOUS METALS EXTRACTED FROM MINED MATERIALS FOR SELECTED MINERAL DISTRICTS IN ARIZONA
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District No. (Plate 1)	Copper (Cu)	Lead (Pb)	Zinc (Zn)	Molybdenum (Mo)	Silver (Ag)	Uranium (U)	Vanadium (V)	Other Metals
J5	97.3%	<½%	2.6%	--	<1%	--	--	Gold <½%
H5	--	--	--	--	--	--	--	Tungsten 100%
A19	22.6%	26.2%	51.0%	--	<½%	--	--	Gold <½%
C12	94.7%	<1%	--	--	1.3%	--	--	Gold 3.2%
D14	41%	36.5%	22.3%	--	<½%	--	--	Gold <½%

Source: Keith, et al., 1983.